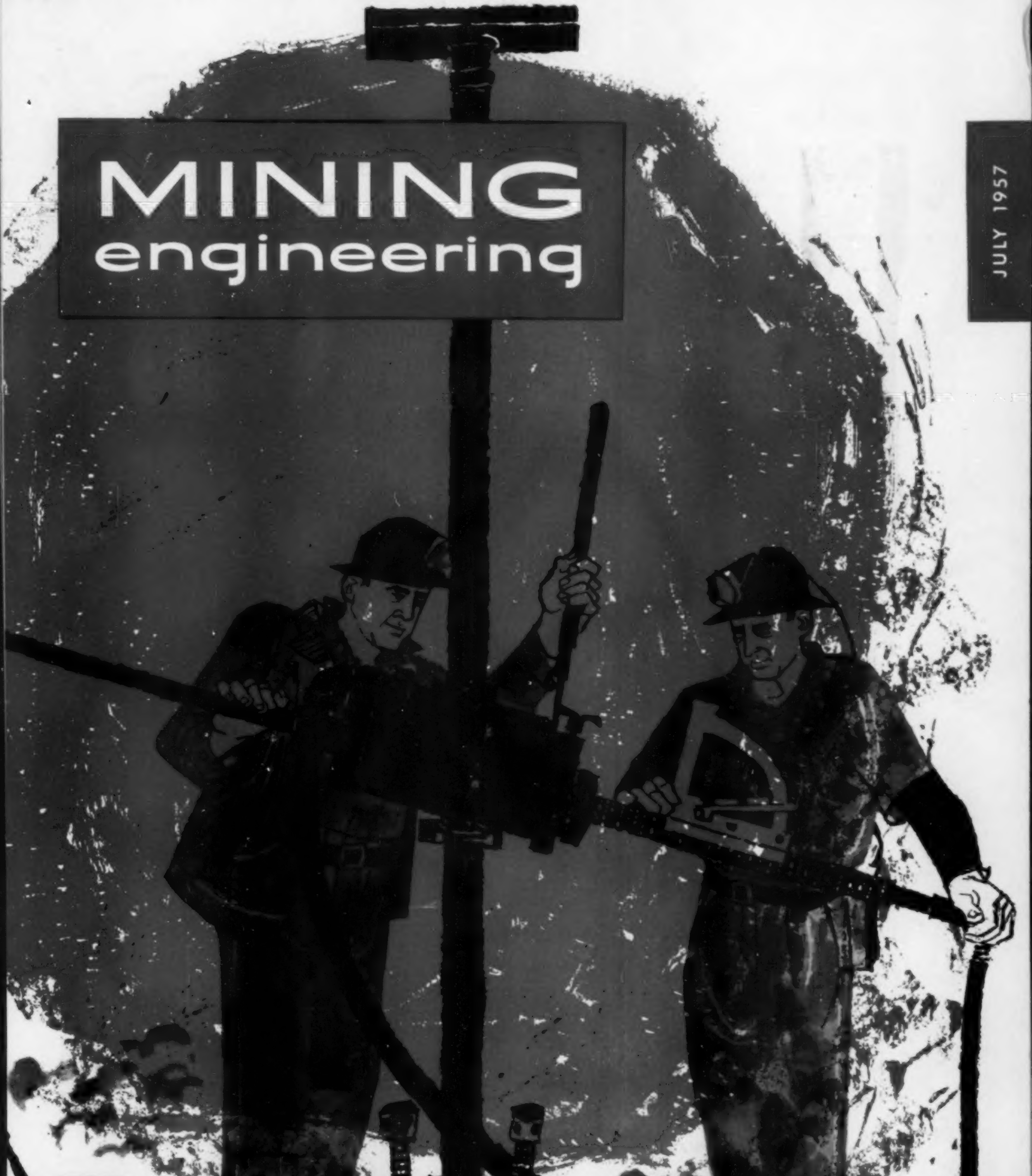
MINING engineering

JULY 1957



The AIME also publishes **Journal of Metals** and **Journal of Petroleum Technology**

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MINING engineering

VOL. 9 NO. 7 JULY 1957

COVER

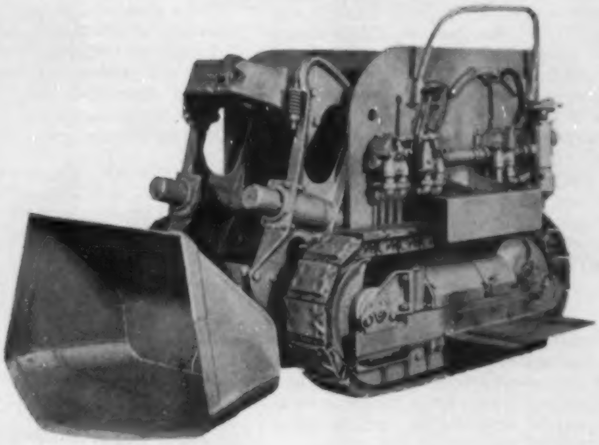
One method of underground exploration involves the use of diamond drills for exploring the limits of newly discovered orebodies. Herb McClure has depicted such an operation in this month's cover sketch. Research on another kind of drilling—rotary-percussive drilling—may be found on page 766.

Know Your Society

ARTICLES

TRANSACTIONS

FEATURES



PERSONNEL

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc. (Agency) operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

— MEN AVAILABLE —

Geologist and/or Mineralogist, B.S. in geology and mineralogy; age 32. Six years experience both field and laboratory. Experience includes mine evaluation, exploration and development work on placer and base metal prospects. Veteran, married. Willing to relocate and travel in U. S. or abroad. Willing to report single status. Desire responsible position with opportunity for advancement. Location, immaterial. M-333.

Manager, for mining or construction project. Thirty years experience South America and Middle East in design, construction, and operation of underground and open cut mining and all phases milling practice. Broad knowledge of cost control, labor relations, and ore beneficiation. Speak Spanish and Italian. M-334.

Registered Professional Mining Engineer, age 39, married. Fifteen years experience mill design and operation, management, research, and mine examination. Three years in South America, three years in Mexico. Other experience includes design and operation of copper and iron properties. Presently operating own company, Sonora, Mexico, copper properties. Consider any location. M-335.

Mine Supervisor, Assistant Mine Superintendent, B.S. in mining engineering, age 27. Four years experience includes chief mine engineer (1000-tpd hardrock underground mine), mine engineer, shift boss, construction supervisor, miner. Location, immaterial. M-336.

Mining Engineer, B.Sc. in mining engineering, age 29. Three years experience underground 1500-tpd mine as chief surveyor, longhole engineer, and some experience in safety department. Prefer western U. S. or foreign. M-337-San Francisco.

Professional Mining Engineer—Management and Operations, B.S. and E.M. Twenty-five years experience in engineering, research, operating, and management, large underground, western Canadian base metal operations. Enviable production record, excellent personnel and labor relations records. Conversational knowledge of Spanish and Scandinavian languages. Desire position with new mining venture in need of experienced guidance. Available immediately. M-339.

Mining Engineer-Exploration, B.S. in mining engineering, age 33. Six years experience underground and surface mining. Exploration and development. Experience includes large and small-scale mining methods, production, sampling, mapping, estimating, and development. Speaks Spanish fluently. Location desired, Latin America. M-338-San Francisco.

— POSITIONS OPEN —

Mining Geologist, 25 to 35, with diversified experience in mining geology, for large independent oil company. Salary, open. Location, Colorado. S2826.

Mine Superintendent, with considerable operating experience, underground mine. Must speak Spanish. Salary, $10,000 a year plus bonus and some allowance for living quarters. Location, Cuba. F5060.

Mining Engineers. a) *Mine Manager,* preferably with experience in mechanized mining and in hydrometallurgy. Should be thoroughly experienced in mine administration and labor negotiations. Salary, $14,000 to $18,000 a year. b) *Assistant Mine Manager,* with experience as above. Salary, $12,000 to $14,000 a year. c) *Mine Superintendent,* thoroughly acquainted with mechanized mining procedures and equipment. Should be good organizer. Ground

(Continued on page 702)

BOOKS

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Principles of Engineering Geology and Geotechnics, by D. P. Krynine and W. R. Judd, *McGraw-Hill Book Co. Inc.*, 699 pp., $10.00, 1957.—This book is a reference work for practicing civil engineers and engineering geologists, and a text for advanced students in these fields. Eleven chapters deal with applications in the design and construction of bridges, buildings, dams, tunnels, runways, and shore structures. Special attention has been given to such problems as permafrost, sedimentation, aseismic design, earth work failures, and the legal side of geotechnics. Illustrations and references supplement the text. •

Experimentation With Large Hole Burn Cut Drift Rounds, by Joseph J. Yancik, Jr., and George B. Clark, Technical Series Bulletin No. 93, *Missouri School of Mines and Metallurgy*, Rolla, Mo., free, 50 pp., 1956.—The work presented is a study of some of the problems encountered in the design of a drift round which employs a large diameter hole as a basic part of the cut. The use of a large hole to provide a second free face for the cut holes is not necessarily limited to drift rounds, but may also be used in other mine openings.

Geochemical Prospecting by Soil Analyses in Montana, by Forbes Robertson, with a chapter by J. H. McCarthy, Jr., and H. W. Lakin, Bulletin 7, *Montana Bureau of Mines and Geology*, Butte, Mont., 94 pp., $1.00, 1956.—The findings of the Montana Bureau of Mines and the USGS on utilization of geochemical prospecting, X-ray spectography, calorimetric methods, and other techniques of exploration and soil analysis in the area are here presented in a comprehensive form valuable to both the professional geologist and the "week-end" prospector.

Uranium Prospecting, by Hubert L. Barnes, *Dover Publications Inc.*, 920 Broadway, New York 10, N. Y., 114 pp., $1.00, 1957.—This book is a concise guide to uranium prospecting, and evaluates all phases of prospecting as an occupation. A discussion of field conditions, ores, development, licensing regulations, purchasing references, and bonuses is included. •

(Continued on page 702)

Books

(Continued from page 698)

Tulsa Geological Digest, Vol. 24, 1957, *Tulsa Geological Society*, P.O. Box 263, Tulsa, Okla., 204 pp., $2.25, 1956.—The papers presented herein range geographically from Bolivia to Wyoming and include such topics as oil migration, evolution of cyclic hydrocarbons, composition of seismic reflections, and interpretation of aeromagnetic surveys. Supplemental lists of geological theses from the Universities of Oklahoma and Tulsa (1955-1956) are also provided. •

Manual on Rock Blasting, *Atlas Copco Eastern Inc.*, Paterson, N. J., and *Atlas Copco Pacific Inc.*, San Carlos, Calif., 95 pp., $3.00, 1957.—The fourth supplement to the internationally circulated manual, first published in Sweden in 1952, contains articles on sublevel caving in Swedish mines, the effects of blasting on nearby structures, and compressed air lines for mines and construction sites.

Coal Science by D. W. Van Krevelen and J. Schuyer, *Elsevier Pub. Co.* Distributed by *D. Van Nostrand Co. Inc.*, 352 pp., $9.50, 1957.—The remarkable developments of the last 15 years in fundamental coal research, especially those of the Central Laboratory of the Dutch State Mines at Geleen, are summarized in this book. Subtitled *Aspects of Coal Constitution*, the book covers technology, geology, petrology, chemistry, physics, and statistical constitution analysis. The final section of the volume deals with physical and chemical properties such as electrical, magnetic, mechanical, and thermal, as well as the behavior of coal on heating and its behavior towards molecular oxygen. References are included. •

The Mining Journal Annual Review, *The Mining Journal Ltd.*, 15 Wilson St., Moorgate, London, E. C. 2, England, $1.50 postpaid, 329 pp., 1957.—World events in mining in 1956. More than 100 articles on technical advances finance, metals, and progress reports on the British Commonwealth's principal mining companies, as well as on other mining and investment companies.

Dexoidation of Steel by C. H. Herty, Jr., *National Open Hearth Steel Committee, AIME*, 29 W. 39th St., New York 18, N. Y., members $7.00, nonmembers $10.00, various pagings, 1957.—This memorial volume to C. H. Herty, Jr., is a collection of his selected papers which emphasizes Dr. Herty's most significant work on the physical chemistry of steelmaking. The papers, generally unavailable today, deal with elimination of metalloids, solubility of iron oxide in iron, deoxidation with silicon and aluminum, and the control of oxide in the open hearth process. In addition, other problems affecting refining reactions and the quality of steel are discussed. The book includes a biographical sketch, a list of Herty's publications and patents, a chapter on the significance of his work, and short biographical sketches of 37 of his co-workers on the Physical Chemistry of Steelmaking Project. •

Personnel

(Continued from page 696)

support problems may be encountered. Salary, $10,000 to $12,000 a year. F5048.

Mine and Mill Superintendent, with experience in vein mining, both underground and surface, mapping and general layout; also good experience in magnetic separation, air table screening for a magnetite uranium operation. Salary, $10,000 to $12,000 a year. Location, East. W4999.

Engineers. a) *Mining Engineer*, young, with underground hardrock mining and surveying experience. b) *Mill Supervisor*, young, with operating, maintenance, and construction experience at gold mine. Single men preferred, with knowledge of Spanish. Salary, open. Location, South America. F4974.

Engineers, for zinc and lead mine. a) *Mining Engineer*, to be in charge of underground mining work. b) *Metallurgist*, to be in charge of flotation mill. Salary, $7200 a year plus housing. Location, Peru. F4956.

Mining or Mechanical Engineer, 35 to 40, married, with open pit experience in stripping, blasting, excavating, transportation, crushing, washing, screening, and drying operations. Excellent opportunity with multi-plant organization. Salary, open. Location, northeast central states. W5069.

Mine Foreman or Superintendent, 30 to 40, preferably graduate, with six to eight years experience open pit operations for responsible position with large company. Good working and living conditions; school facilities limited at present. Manganese concentrates. 1100-ft elevation, good climate. Salary, $9,000 to $12,000 a year. Location, South America. F5085-S2938.

Mining Engineers, for lead-zinc mine. Good foundation in underground mining methods and experience in handling labor required. a) *Assistant Mine Superintendent*. b) *General Mine Foreman*. Knowledge of Spanish essential. Location, Mexico. F5074.

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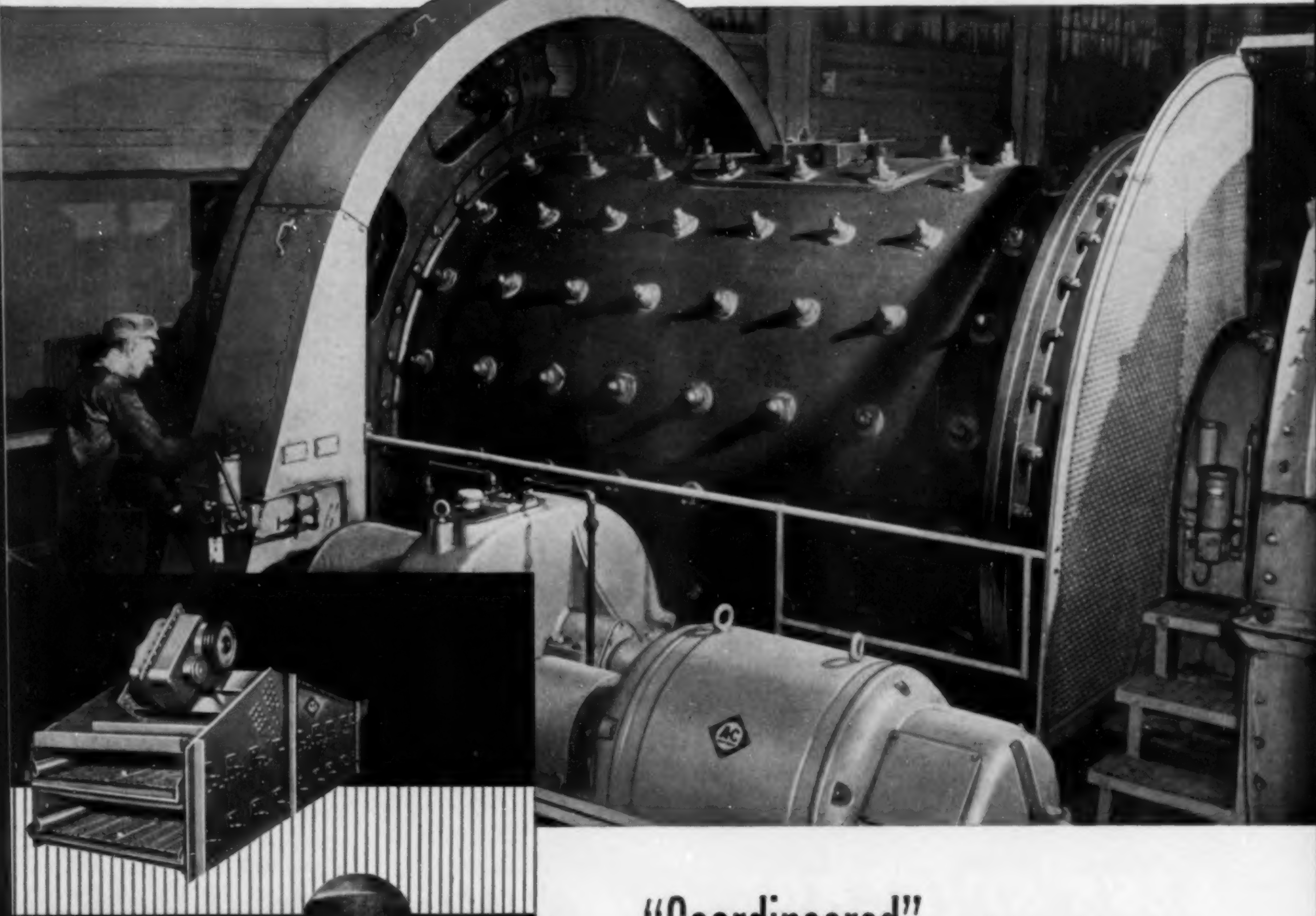

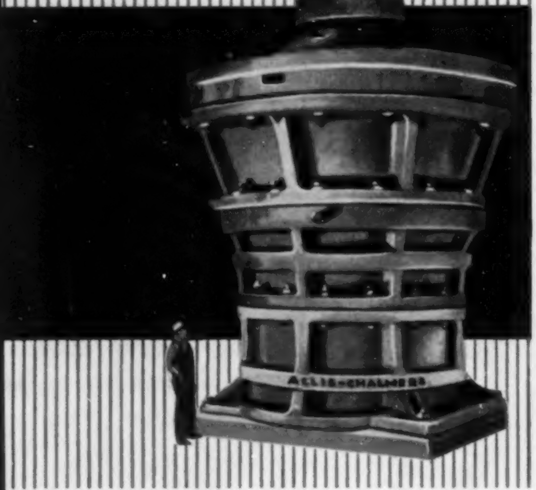

"Coordineered" Equipment for the Mining and Rock Products Industries

GRINDING MILLS—Whether your process calls for individual mills or a grouped stage grinding series, Allis-Chalmers can make a right-for-the-job recommendation from seven different types of grinding mills.

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Out where performance alone is not enough!

Near Butte, Montana, a CAT* DW20 Tractor works on a haul road at an open-pit copper mining operation. The road, half a mile long and 60 feet wide, had to go in fast. So a pair of DW20s with Scrapers dumped some 1600 cu. yd. of dirt per 8-hour day, and did it day in, day out till the job was done.

And that's the point: *day in, day out* till the job is done. For, on the hard jobs, performance alone, while mighty important, is not enough.

Sure, DW20 units give superior performance. Big capacity. Load easily. Big rimpulls that overcome grade and rolling resistance on rough roads. Ejection that gets rid of any kind of material quick. And, of course, high speed.

But the DW20 does more than a good job. It *stays* on that job. It shrugs off the down time that hurts you in your cost-per-yard figure. Your Caterpillar Dealer is ready with facts and figures to prove that the built-in durability of the DW20 means dollars and cents to you. He's ready, too, with expert service—and with replacement parts you *know* you can trust.

P.S.: Your Caterpillar Dealer will demonstrate the DW20 on your job, at your say-so—with any of its famous running mates: the new No. 456 Scraper with LOWBOWL design; the Athey PH20 Wagon specifically designed as an economical coal hauler (56 cu. yd. heaped load); and the Athey PD20 side dump Wagon with a heaped capacity of 25 cu. yd.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

WANTED—
THE HARD WORK

Manufacturers News

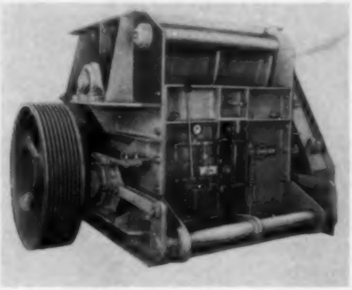
• FILL OUT THE CARD FOR MORE INFORMATION •

Underground Transformer

A fire and explosion-proof dry type transformer in 5-kv class and below is offered by *Allis-Chalmers* for underground service. It can be safely placed in flood areas, contaminated atmospheres, and in open work spaces without the use of vaults or barriers. Designed low for dragging to its work site, the sealed unit is claimed to require a minimum of maintenance. **Circle No. 1.**

Coal Crusher

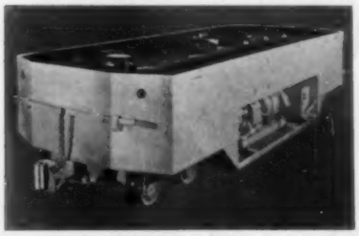
Recommended for coal or similar materials, the *McLanahan & Stone Corp.* Black Diamond crusher will receive run-of-mine or open pit feed and reduce to as small as ½-in. size. Three rolls are used. One crushes primary feed against a curved plate;



the other two, with opening adjustable up to 6 in., perform secondary reduction. Four roll widths are available—24, 36, 48, and 60 in. All are of 18-in. diam. **Circle No. 2.**

Mine Fire Truck

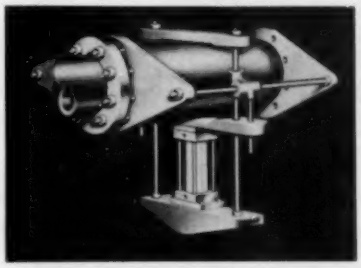
A new highly mobile mine fire truck by *Mine Safety Appliances Co.* has a capacity of 2100 gal and is compactly designed for maneuverability. Standard unit is 50 in. high, 7 ft wide, and 18 ft long. A 20-hp, 3500-rpm electric motor powers a pump that delivers 100 gpm of water



and can throw a 100-ft horizontal stream. Ruggedly constructed, the unit may be left underground. Hosing is impervious to oil, acid, rot, and vermin. Unit can negotiate a No. 2 turnout with ease—standard size wheels have 5-in. treads for stability. **Circle No. 3.**

Pinch Valves

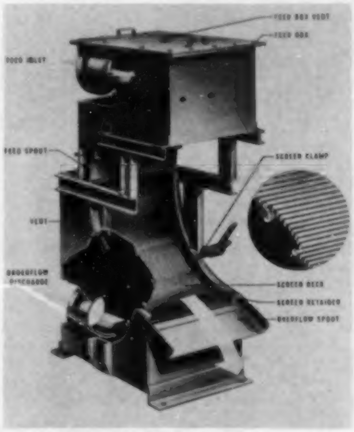
Mine & Smelter Supply Co. has new models of the Massco-Grigsby pinch valves for handling abrasive and corrosive pulps and liquids. Sizes range 1 to 14-in. ID, for pressures to 150 psi and temperatures to 200°F. Major new feature is a Hy-



dral-Air operating mechanism that consists of an air-hydraulic pump which can operate several valves as a centralized unit. It can also be equipped to automatically control liquid level in tanks or the rate of flow in pipe lines. Valve is available with rubber or neoprene sleeves. No working parts contact pulp or liquids. **Circle No. 4.**

Stationary Screen

A new stationary screen from *Dorr-Oliver Inc.* for continuous wet screening of slurries is particularly adaptable to separations in the 8 to 48 mesh range. Designated DSM, the screen is a concave, horizontal-



wedge-bar type secured in a stationary housing. No power is needed for operation, and the DSM is available in four widths: 1, 2, 3, and 4-ft. Vertical size is the same for all. Capacity is about 200 gpm per ft of width when making a 48 mesh separation and up to 500 gpm per ft in producing an 8 mesh separation. **Circle No. 5.**

Crawler Drill

Ingersoll-Rand has a new knee-action crawler drill, the Crawl-IR, mounted on tracks driven by air motors. All boom and feed-tower adjustments are hydraulically controlled. Horizontal boom swing allows hole spacing of almost 10 ft. Holes can be drilled from ground level to 7 ft without moving the unit. **Circle No. 6.**

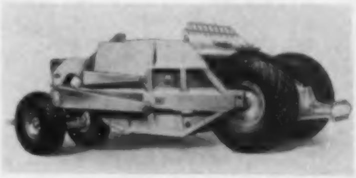
Chain Repair Link

Repair of hoist and drag chains is no problem with a new cast manganese steel link by *Kensington Steel.*

It consists of two identical half links and a combination key and wedge. The half links are inserted through the ends of the chain to be joined. When the wedge is driven into place, it bends the key and thus locks the link together. No welding, burning, or riveting is needed. Link is available in sizes from 1 to 3 in. **Circle No. 7.**

Bigger Payload

A new scraper to match the hauling power of the D8 and D9 crawler tractors is available from *Caterpillar Tractor Co.* The No. 491 replaces the No. 90, and features a payload capacity of 82,000 lb—12,000 lb greater than the former model. The apron opening has been increased 15 in. and bowl sides have been made higher. **Circle No. 8.**



(21) GYRATORY CRUSHERS: Bulletin 1126 from *Traylor Engineering & Mfg. Co.* has 40 pages of illustrations, cross-section drawings, specifications, and features of the Traylor TC gyratory crushers. Feed openings range 30 to 60 in., capacities from 345 to 4100 tph. Included are complete instructions for assembly, erection, lubrication, operation, and repair of these primary crushing units.

(22) TRACTOR SHOVELS: *Pettibone Mulliken Corp.* offers a bulletin on their line of Speedall tractor shovels. Largest of these is the Speedall 250 which boasts a lifting capacity of 21,000 lb. Its capacity (2½ cu yd struck) can be raised to 3¼ cu yd by "Speedload" heaping. Two other models, the 1¾ cu yd model 175 and the 1¼ cu yd model 125, are also detailed in new Bulletin P-362.

(23) BATTERY POWER: A newly revised reference catalog on motive-power batteries details new features of Exide-Ironclad units for mine vehicles and electric industrial trucks. Exide's grid alloy Silvium is claimed to have high resistance to electrolytic corrosion. The 12-page catalog is published by Exide Industrial Div. of the *Electric Storage Battery Co.*

(24) INDUSTRIAL GEARING: *Westinghouse Electric Corp.* offers a booklet from its Gearing Div. covering the steps of specialized machining and heat treating necessary to the production of gears for mill machinery, mining shovels, cranes and hoists, locomotive drives.

(25) COAL HANDLING: "The Money-Saving Way to Stock-Out, Reclaim, and Compact Coal," a new booklet from *International Harvester Co.* describes handling performances of IH units. An equipment "select-o-graph" helps match units to hauling requirements. The 20-page brochure (CR-618-G) is offered by the Construction Equipment Div.

Free Literature

(26) GAS REGULATORS: Forty-page Catalog 806 from *Air Reduction Sales Co.* details a line of pressure regulators for industrial compressed gases. It deals with various cylinder, manifold, and pipeline regulators, and a variety of specialized equipment such as laboratory and metering regulators and gas proportioners. Flow and pressure charts are supplied in graph form.

(27) LUBRICANT: A 16-page booklet covering a line of molybdenum disulfide lubricants has been published by *Alpha Molykote Corp.* Featured are a selection table, photos of a variety of uses, and a section on bonded solid film lubricating coatings. Molykote lubricants may be used under extreme pressure and are said to provide effective dry lubrication in dusty atmospheres.

(28) LABORATORY SAFETY: Newest edition of the *Fisher Scientific Co.* manual of laboratory safety has been made available. Covered are accident prevention, first aid, fire prevention, safety equipment. Included is a section on handling radioactive materials.

(29) BELT CONVEYOR IDLERS: A new 8-page pamphlet from *C. O. Bartlett & Snow Co.* describes a complete line of belt conveyors. Bulletin 119 includes data on troughing, flat, self-aligning, rubber disc, and return designs. Rolls are 4, 5 and 6-in. diam; fittings use either Timken or Bartlett-Snow "sealed for life" bearings. Accessories detailed include belt trippers, take-ups, plows.

(30) GAS EQUIPMENT: Industrial gas manifolds with automatic controls are described in a new 24-page Oxweld catalog offered by *Linde Co.*, division of Union Carbide Corp. Included are acetylene generators capable of delivering from 100 to 9000 cu ft per hr. Recommended uses and specifications are given for a complete selection of equipment for gas piping systems, including hydraulic back-pressure valves, relief valves, station valves, oxygen filters, and station check valves. Form 4486 supplies the information.

(31) NON-CLOG SPRAY: *Booth Co.* has a data sheet (No. 571) covering a non-clog launder spray for flotation plants. Made to fit a 1-in. pipe, the spray features a rubber diaphragm which allows passage of foreign material without stopping water flow. Four different size orifices may be used by a simple change of diaphragms. Orifice sizes are 1/16, 3/32, 1/8, and 5/32-in. diam.

(32) BLASTING HAZARD: Recent investigations indicate that the hazard of radio-frequency energy to blasting operations has been greatly exaggerated, according to a report just approved by the Institute of Makers of Explosives. The 9-page booklet replaces an earlier publication on the subject. Pamphlet No. 20 is available from the Explosives Development Section of *Atlas Powder Co.* Booklet describes in detail how to determine the extent of RF energy hazard in any area. Potential hazard is also analyzed of such types of RF energy sources as microwave relay, radar, and Loran.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

7

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Oct. 15, 1957—if mailed in U. S. or Canada

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51	52	53	54	55	56	57	58	59	60
61	62	63	64						

Students should write direct to manufacturer.

(33) ROAD MACHINERY: *Huber-Warco Co.* offers a 32-page publication containing data on a line of road machinery. Bulletin HWC 541 details the Huber-Warco motor graders, maintainer, tandem rollers, and three-wheel rollers.

(34) ALTIMETER-BAROMETER: A pocket-size Swiss altimeter-barometer is available from *William Wolff Co.* in two improved models. The Thommen 3D15 will measure altitudes ranging to 15,000 ft; the 3D17 to 21,000 ft. Measuring range of the barometer is 31 to 22½ in. of mercury.

(35) MATERIALS HANDLING: *Denver Eqpt. Co.* has just published a 20-page mill and plant equipment bulletin (No. G3-B59) showing latest models in crushing, grinding, screening, classifying, and materials handling machinery. Also covered are dryers, thickeners, mineral jigs, testing sieve shakers, and automatic samplers. Denver's ore testing services are outlined.

(36) CAR PULLERS: Jones Machinery Div. of *Hewitt-Robins Inc.* has a new 32-page booklet on car pullers. Installations are described of various types of car pullers for moving freight cars, barges, scrap buggies, and other types of industrial transfer cars.

(37) FEEDERS: Catalog 571 from *Simplicity Engineering Co.* describes all models of the Simplicity vibrating pan type Os-A-Veyor and grizzly feeders. Built in capacities up to 1000 tph, the bulk material feeders are shown with all specifications and engineering information.

(38) NOISE CONTROL: An 8-page brochure illustrates with charts and photographs the application of pneumatic mufflers for the elimination of exhaust noises of air-operated equipment. Performance is emphasized in this bulletin from *Allied Witan Co.*

(39) BELTS & HOSE: *Gates Rubber Co.* says that coal mines are cutting costs with Gates V-belts, industrial hose, and rubber faced plate in their new Industrial Survey DH 426. Illustrated cases outline results obtained by owners and operators at mines, washeries, and processing plants.

(40) HELIWELDING: All equipment used in applications of *Air Reduction*

Co.'s tungsten arc Heliweld process is shown in 20-page Catalog 2300.

(41) WIRE ROPE TIPS: A booklet of wire rope recommendations for general contractors is available from Hazard Wire Rope Div., *American Chain & Cable Co. Inc.* The 16-page publication supplies data on the many grades and construction of wire rope Hazard provides for such units as hoists, cranes, draglines, drilling machines, shovels. Accessories and cable assemblies are included.

(42) LITHIUM: "Presenting Lithium," a 15-page tabbed booklet, has been offered by the recently formed *American Lithium Institute*, Princeton, N. J. Described are properties, uses, research potentials, and availability of lithium and its compounds. The data outlines research possibilities and discusses the functions of the institute in assisting in the use of the metal.

(43) INDUSTRIAL HOSE: A 40-page catalog of *Weatherhead Co.* products is newly available. Detailed information covers bulk industrial hose, permanent assemblies, swivel adapters, and assembly and installation. An agent selector chart lists over 180 elements; resistance ratings of varicus hose materials are included.

(44) ACETYLENE BLOWPIPES: Three Oxweld welding blowpipes are described in a 6-page folder from *Linde Co.*, Union Carbide Corp. division. Operation is possible at pressures below 1 psi. Attachments for conversion from welding to flame-cutting operations on metal up to 8 in. thick are also described.

(45) HEAVY-DUTY COMPRESSORS: SVO diesel-engine compressors for use in industrial plants, mines, and chemical plants are shown in a new bulletin by *Ingersoll-Rand.* Featured unit combines a 4-cycle V-angle engine and a slow speed horizontal compressor on a single crankshaft. Form 3207 lists five available sizes which range in capacity from 1065 to 3200 cfm at 100 psi. SVO is built for continuous full-load operation.

(46) MOTIVE POWER: *International Harvester Co.* announces that copies of a new booklet "Power in Action," are available from the Construction Machinery Div.

(47) CONVEYOR BELT REBUILDING: *Conveyor Belt Service Inc.* says belts costing $5 to $100 per ft have been successfully rebuilt and returned to service after end-to-end rips, transverse cuts, impact breaks, cover tears, and edge injuries had apparently marked them for discard. Details of the company's national repair and rebuilding service are detailed in a new illustrated booklet.

(48) ROAD DUST CONTROL: *Crown Zellerbach Corp.* says that dust on dirt roads is being eliminated by several large open pit copper mines with low-cost applications of Orzan AL-50. The material, derived from the pulping of wood, is delivered to the mines in tank cars and diluted with water before sprinkling. It forms a hard, stabilized road by bonding surface gravel. Water soluble, the Orzan compound rebonds with repeat sprinklings. One sprinkling is claimed sufficient to withhold dust for three weeks.

(49) PRESSURE FILTER: A revised 4-page brochure on the Sweetland filter by *Dorr-Oliver Inc.* covers operation and advantages of this batch pressure filter. Bulletin 7400 supplies a typical installation flowsheet and a chart outlining specifications of standard units. Principal components of the filter are a split pressure shell with a hinged bottom and a series of circular filter leaves.

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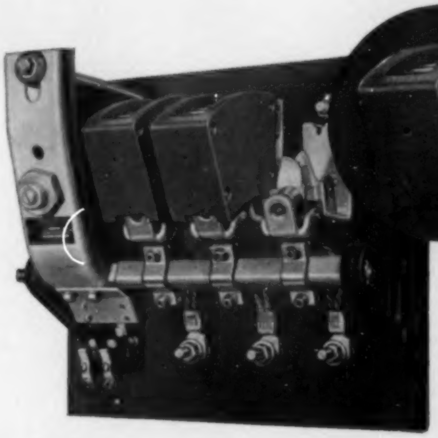
for fast arc interruption... without blowout coils

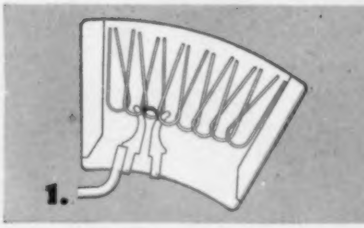
ALLIS-CHALMERS

TYPE 425 CONTROL

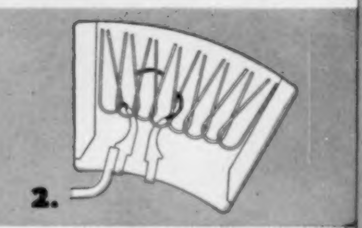


featuring ACBO arc-centering blowout chutes for 50 to 400 hp

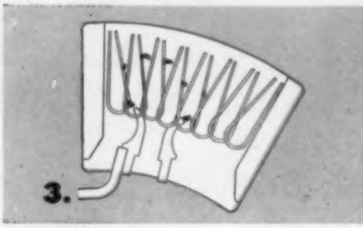
The advanced electrical design of Allis-Chalmers Size 4, 5 and 6 control incorporates a modern principle of arc interruption for low voltage, high horsepower applications. The *ACBO* arc chute utilizes principles of magnetic action and thermal convection to center, rupture and extinguish the arc . . . quickly. Fast arc interruption assures maximum contactor efficiency, improves performance — greatly prolongs contact and chute life.



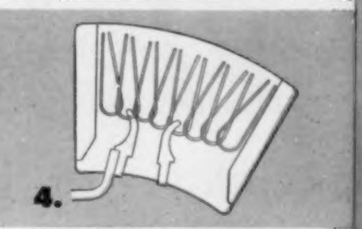
1. Arc across contacts as they start to open.



2. Strong blowout action forces arc to center.



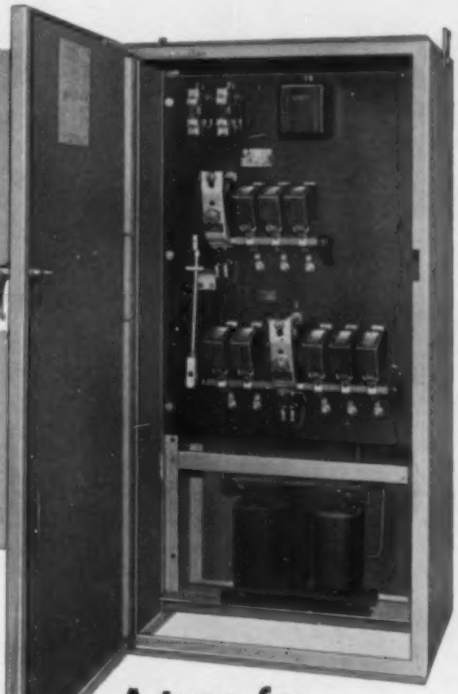
3. Arc rupturing.



4. Contacts fully open— arc extinguished.

Simplified mechanical design

- Streamlined clapper-type construction eliminates many parts.
- Accessibility simplifies maintenance and inspection.
- Installation is fast and easy . . . sensible enclosure dimensions provide ample wiring space.



A type for any application

Type 425 control offers a wide selection of starters and contactors for any application. For detailed information, call your A-C Control Distributor or your local A-C District Office . . . or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin. Ask for Bulletin 14B8615.

ACBO is an Allis-Chalmers trademark.

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

A-5343

60 ft. drop over rocky cliff—yet no power failure with Anaconda Mine Power Cable!

This cable is exposed to about as rugged a set of conditions as any cable is likely to meet. It has been pulled over sharp rocks ... dropped over a 60 ft. cliff ... and lies unprotected under sun and harsh weather day after day. Yet it has given unfailing service.

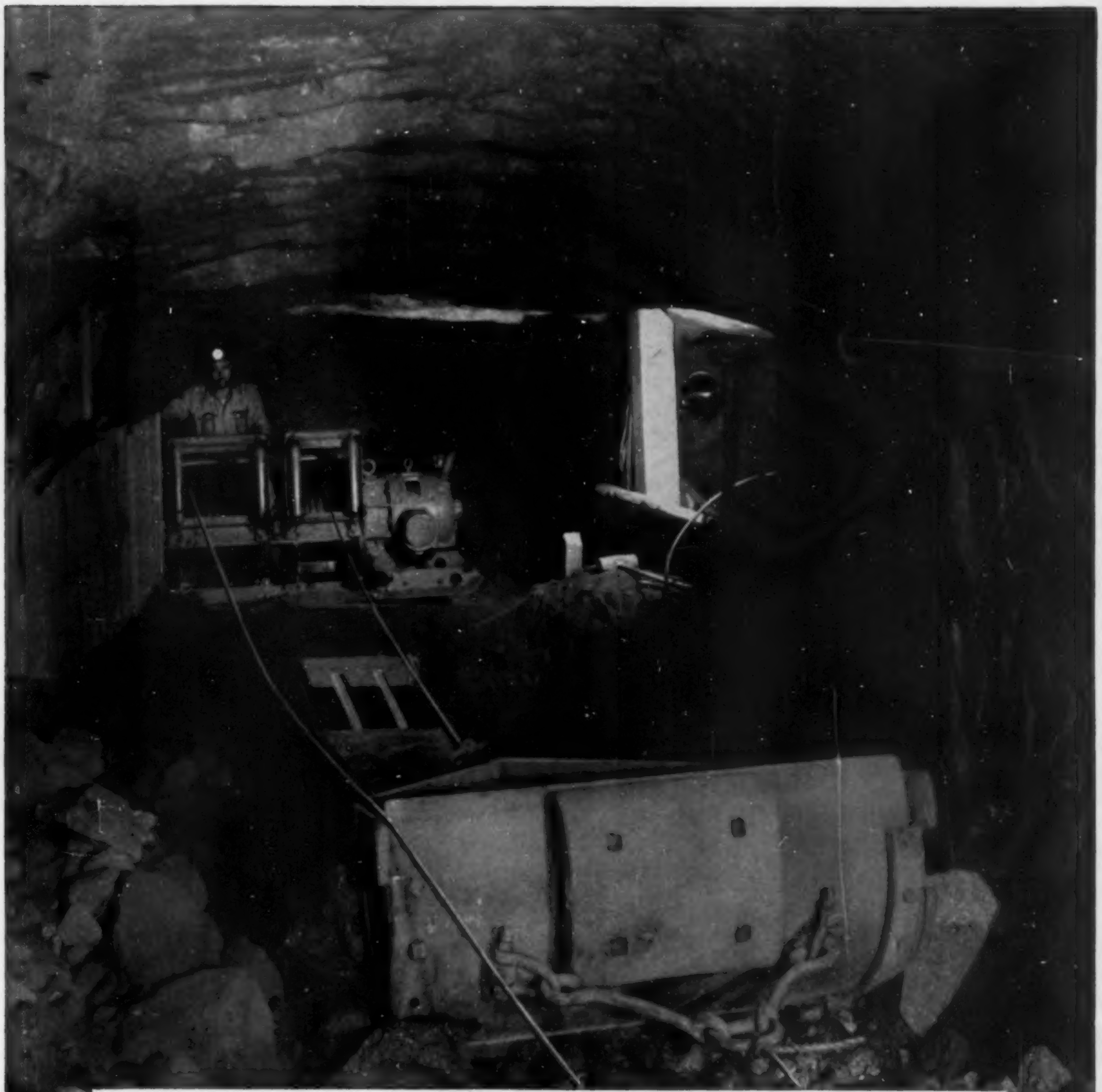
Why? Anaconda Mine Power Cable is designed and made by people who know *both* mining and cable engineering!

NEOPRENE JACKET is extra tough ... has real flexibility and great strength. It resists abrasion, mechanical abuse, flame and water.

BUTYL INSULATION has superior long-aging characteristics . . . excellent resistance to ozone, heat and moisture. And it has high dielectric strength.

The Man from Anaconda or your Anaconda Distributor can give you full information about this durable, low-cost mine power cable. Or write: Anaconda Wire & Cable Company, 25 Broadway, New York 4, N. Y.

SEE YOUR ANACONDA® DISTRIBUTOR
FOR MINE POWER CABLE



why "unit assembly" construction adds up to **MORE TRIPS PER HOUR**

Your choice of an Ingersoll-Rand double or triple drum Scraper Hoist . . . either air or electric . . adds up to more trips per hour, less maintenance and longer hoist life. Each unit consists of its own barrel-type housing, rope drum, gearing and clutch which operate independently. This means you can select the right combination of pulling power and speed. It also means that return rope speeds are at least ⅓ faster than pull rope speeds.

Selection of the right scraper hoist for your job is easy when you choose from the wide range of "Unit Assembly Hoists". Write for Bulletin 5300A. Engineering help on your scraper mucking problems is available for the asking—no obligation.

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11 Broadway, New York 4, N.Y.

8-532

To Drill Large New Mexico Tract

E. J. Longyear Co. and Yucca Mining & Petroleum Co. Inc. jointly announce contracts covering the exploration of approximately 16,000 acres in McKinley County, N. M. The Yucca property to be drilled is six miles east of Ambrosia Lake where some 64 pct of known U. S. uranium reserves are located. Designated the San Mateo Dome project, the program has budgeted more than half a million dollars for 1957 exploration and a similar budget has been pre-arranged for next year. E. J. Longyear will manage the exploration, which will be financed by Lisbon Uranium Corp. and Mineral Project-Venture B. Ltd.

New Saskatchewan Potash Mine

International Minerals & Chemical Corp., whose Carlsbad, N. M., mine supplies about 20 pct of U. S. potash products, says its new mine in the Canadian province of Saskatchewan contains area reserves ample for production at twice the rate at Carlsbad. A shaft is being sunk to reach a horizontal seam at the 3000 level. Orebody is favorable to the room and pillar method used at Carlsbad.

New Listing, New Names

U. S. Borax & Chemical Corp. has almost completed its $20 million expansion program at Boron, Calif. Shares of the company were listed on the New York Stock Exchange for the first time May 20. . . .Union Carbide & Carbon Corp. has shortened its name to Union Carbide Corp. Three division names have also been changed. Carbide & Carbon Chemicals Co. has become Union Carbide Chemicals Co.; Linde Air Products Co. changes to Linde Co.; and Carbide & Carbon Realty Co. will be known as Union Carbide Realty Co.

Mica Purchase Program Supplemented

General Services Administration is offering five-year contracts for the delivery of stockpile mica from foreign sources to stimulate foreign development. Heretofore such contracts have been limited to two or three-year terms. Importers also will be permitted to deliver up to a pound of nonstrategic mica for each pound that meets stockpile specifications. Nonstrategic material will be held in inventory reserve.

Lithium Development Plan Ratified

Montgary Explorations Ltd. of Toronto and American Metal Co. Ltd. have agreed on an option that will give American Metal a 60 pct interest in Montgary's lithium mine at Bernic Lake, Manitoba. More than 27,000 ft of diamond drilling by the two companies has indicated a spodumene orebody of almost 8 million tons averaging 1.35 pct Li_2O. A headframe has been erected, and sinking of a three-compartment shaft has progressed to 75 ft.

Have you tried the new dipper teeth...

that are already saving money for all major mining companies on the Iron Range?

Facts about Wearpact® Steel

The best combination of hardness and toughness available anywhere

About 2½ years ago, a new alloy was developed with unusually high hardness—477 minimum Brinell—and yet was *tough*. Able to stand up, without flow or distortion, under the worst kind of abrasion and impact. Now used with excellent results on crusher liners, grousers, end bits, corner shoes and cutting edges.

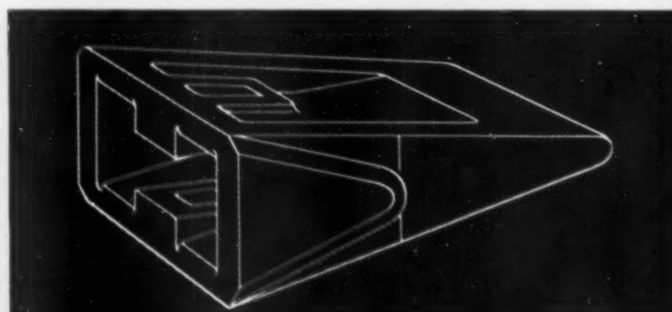
Today, for example, only 30 months later, every major mining company on the Iron Range is using Wearpact Steel teeth. And what a record these teeth have made! Reports from a taconite mine, where service conditions are worst of all, show that manganese teeth last an average of 3 shifts—with two repointings. But the same reports show that Wearpact Steel teeth average 12½ shifts—*straight through*. No more pulling teeth off the shovel after each shift; no more piles of teeth in the welding shops, each waiting for an expensive rebuilding job.

Hardness and toughness alone didn't account for all this increase in service life. The Wearpact teeth were of a different design . . . with long, sweeping cutting edges that stay sharp; *slice* rather than ram through the ore. No other commonly used alloys would permit designs like these; only Wearpact has the necessary tensile strength and high yield point. And remember; you don't work-harden Wearpact. It's hard—clear through—as shipped. Teeth are ready for tough service the minute they're installed. No hardfacing needed.

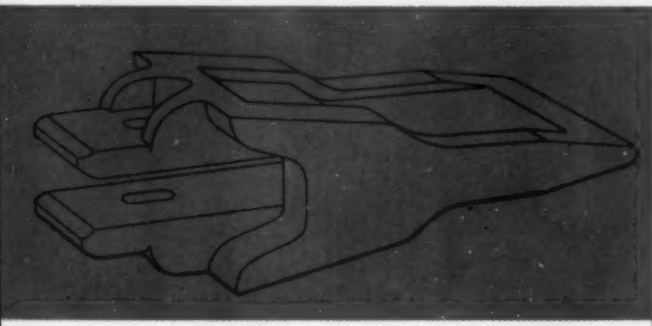
How much money can Wearpact Teeth save in YOUR mine?

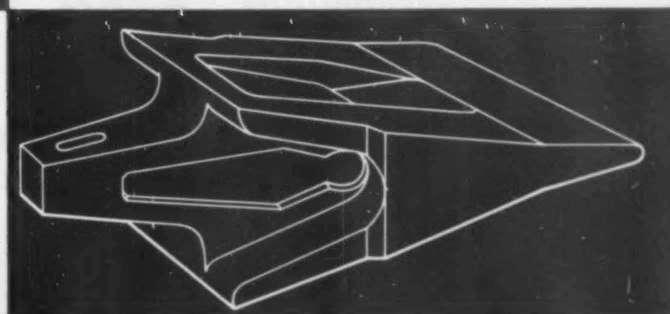
That depends on your operating conditions, of course. Find out for yourself—with your own cost figures—that Wearpact can save money for you, as it has in other mines. Now is the time to arrange for a test of Wearpact. Write today for name of your nearest ASF Representative, or use the coupon below.

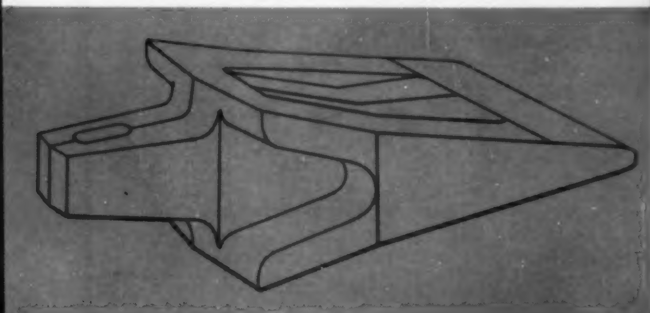
WEARPACT Style 3

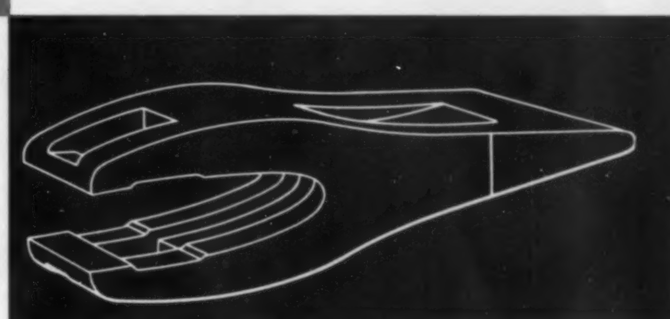


WEARPACT Style 1









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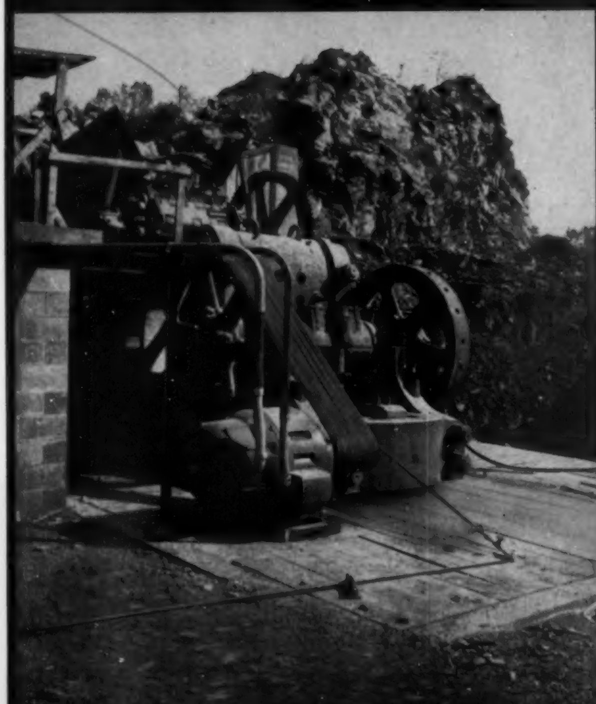
custom-made because he
gets something **EXTRA**



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For over half a century, producers have specified Traylor-made Jaw Crushers to insure extra hourly production with lower operating costs per ton. There are four types of Traylor-made Jaw Crushers to fit every primary breaking requirement. Feed openings range from 8″ x 12″ to 60″ x 84″; capacities from 4 to 1000 tons per hour. For bulletin on Traylor Jaw Crusher suited to your needs, write stating product size and capacity desired.

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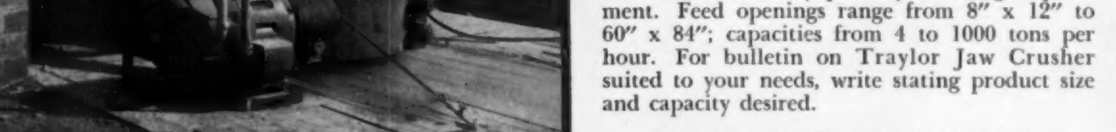


BALL MILLS | ROTARY KILNS | PRIMARY GYRATORY CRUSHERS | APRON FEEDERS | JAW CRUSHERS | SECONDARY GYRATORY CRUSHERS

Stripping Shovel Takes 80-Ton Bites

Kentucky bituminous mine makes use of a huge new unit taller than a 13-story building. Shipping the shovel required more than 70 railroad cars.

River Queen, one of the largest mobile land machines ever built, has swung into operation, stripping over-burden from coal reserves of the River Queen Coal Co. mine in western Kentucky. The largest power shovel ever manufactured by Bucyrus-Erie Co., the River Queen is a hefty worker weighing in at 2400 tons, and equipped with a gargantuan dipper of 55-cu yd capacity.

Designated the Model 1650-B, the long range stripping shovel is equipped with a 145-ft boom and an 86-ft dipper handle enabling it to dump rock and earth overburden nearly 300 ft away from the digging point and to stack it more than 100 ft high.

The River Queen will excavate only down to the coal seam; coal loading will be done by smaller power shovels. Diesel haulers will then take the coal to a 1000-tph washing and screening plant.

River Queen mine is owned jointly by W. G. Duncan Coal Co. and Peabody Coal Co., and is operated by Peabody. In full operation, the mine will be producing 2 million tons of bituminous coal annually.

Despite the size of the River Queen, one operator controls the entire digging operation with two hand levers and two foot pedals. A glass-enclosed cab, perched 30 ft above the ground, was constructed to provide maximum visibility for the operator. An 8-ft wiper keeps the windshield clean when it rains.

An air-conditioning system cools the cab and four telephone sets are employed in an inter-communication hookup. Cab accessories include tile flooring, wood paneling, a water cooler, clothes lockers, and a foreman's desk.

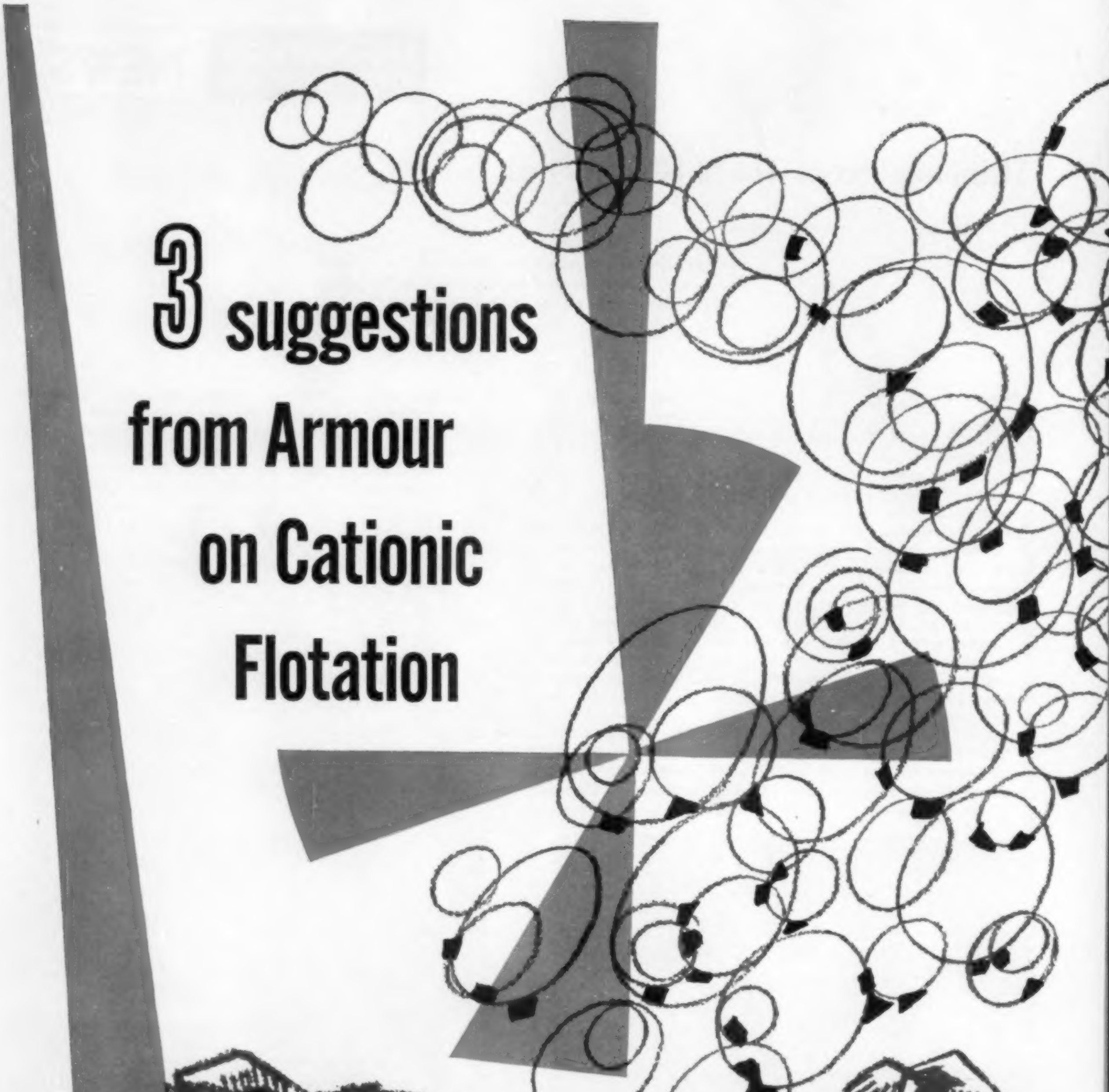
A loudspeaker on the boom enables the operator to keep in contact with ground men and those in the pit area. A ground man directs all moves from an electrical control box mounted at the base of the machine.

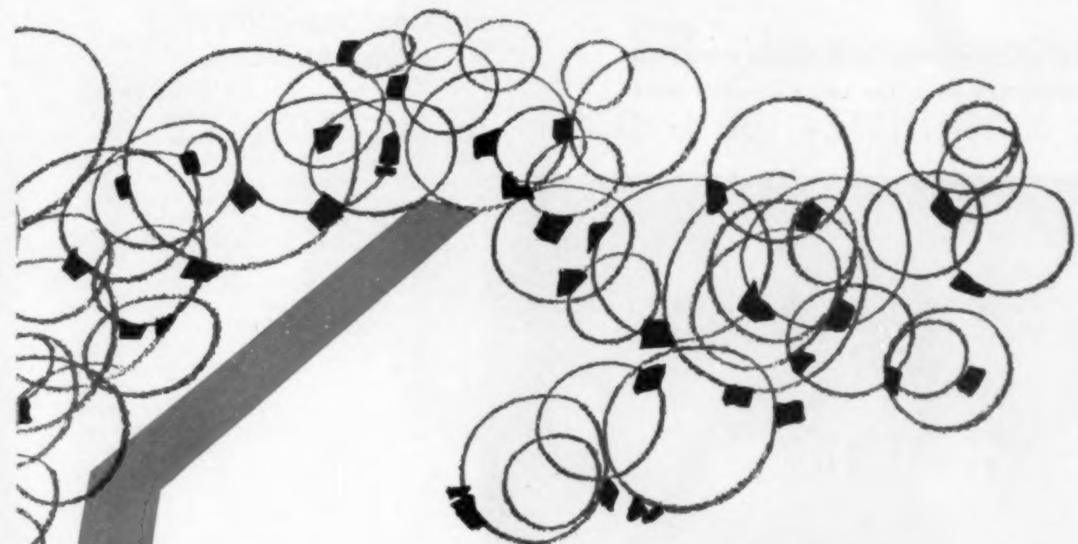
The River Queen is mounted on four independently motor-driven crawler type trucks, each weighing more than 200 tons. Even if the machine is on uneven ground, jacks keep the revolving upper frame level during operations.

Fifteen electric motors power the shovel—eleven for digging and four for propelling. Main motors are two 1500-hp a-c motor-generator-set, synchronous driving units. All were supplied by General Electric.

From the ground to top of boom sheaves, the River Queen stands 140 ft tall. Here it is uncovering two seams of bituminous coal in a western Kentucky open pit.

Two men are no mouthful for the River Queen's 55-cu yd maw which can take more than 80 tons of rock and earth in a single pass.


3 suggestions
from Armour
on Cationic
Flotation



1. Test this new cationic collector that needs no water solubilizing. New, low cost Armoflote® 54-38 is easier to handle and simpler to use than amines or amine acetates. Tailor-made for flotation of silica from phosphate rock and minerals from pegmatite. Liquefies between 80-100°F. Contains no inert solvents. Delivered in drums or tank cars and *can be blended with secondary collector or frother!* Stores indefinitely or can be used immediately. Send for sample and observe its greater tolerance to slimes and hard water.

2. Investigate the high quality performance of Armacs® in floating silica from iron oxides. The ore in the following typical test was a Mesabi taconite, a mixture of slatey and cherty taconites, holding magnetic iron (17.0 parts) and non-magnetic iron (15.7 parts), the remainder mostly silica. Grinding to 95% minus 100 mesh produced liberation. Desliming was necessary. Iron depressant was starch. Pulp pH: 10-11.

Lbs.	Lbs.	% Fe			Iron Recovery Based on
Armac CD	Frother	Silica Conc.	Middlings	Tailings	original ore
0.80	0.20	6.27	29.62	50.9	77.9

Our flotation experts will be pleased to discuss your iron oxide flotation problems with you.

3. Explore these newly developed collectors that have shown exceptional promise in varied fields. Our research reveals the value of unusual new liquid amines and amine acetates in a wide variety of mineral separations. Request literature and samples for your own cationic flotation testing. Solubility data available.

Specifications of amine acetates (representative lots)

	Armac O	Armac OD
Iodine value	72.7	69.4
Primary amine acetate	89.6	98.5
Secondary amine acetate	6.3	2.0
Neutralization	99.0	96
Moisture	0.73%	0.89%
Cloud point	82°F	98°F
Pour point	40°F	65°F

The corresponding amines (Armeens® O and OD) are available for testing purposes. Request descriptive literature and sample.

• • •

Armour Cationic chemicals increase your recovery of the following minerals: *Amblygonite, Spodumene, Ilmenite, Phosphate, Barite, Beryl, Feldspar, Fluorspar, Hematite, Mica, Potash, Salt, Silica Vermiculite.*

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Shaft Mucking Crew Uses Skid-Shovel

Bucket loader converted to electric power proves satisfactory as a low cost coal shaft sinker.

This skid-shovel-dug shaft of the Christopher Coal Co. is now at the 315 level but will go to 430 ft before completion.

Looking for a practical way of digging mine shafts which would speed up the work and reduce accidents, members of the Williamson Shaft Contracting Co. of Columbus, Ohio, developed a unique method which employs a 1-cu yd skid-shovel.

Their method is to blast shaft rock loose for a depth of 8 ft, lower the skid-shovel and load the loosened rock and earth into 2-cu yd rock buckets which are then hoisted out by a stiff leg derrick. When this is completed, forms are put in place and concrete retaining walls are poured. The operation is repeated when the wall lining has set.

For safety the contractors converted an International TD-6 skid-shovel from the standard 55-hp diesel to an explosion-proof electric motor. Dimensions of the machine were found satisfactory for operation in a shaft as small as 15x38 ft. After numerous tests above ground, the shovel began a shaft in Greene County, south of Pittsburgh, and has operated successfully since.

Mining Congress Coal Show Draws Large Audience

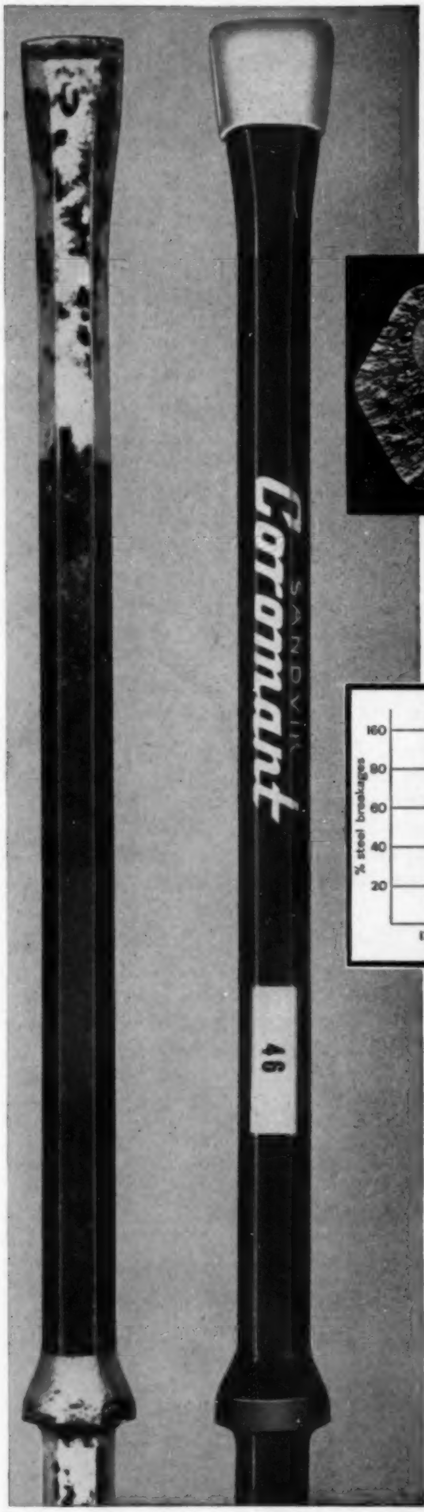
The biennial Coal Show of the American Mining Congress got under way May 13 in Cleveland's Public Auditorium with more than 10,000 coal industry people on hand for the combination convention and machinery exposition.

Convention sessions constituted a comprehensive review of progress in modernization of coal mining techniques and preparation methods, improvement in safety practices, and developments in machinery and other equipment. For producers of industrial minerals such as limestone and phosphate, two sessions on their particular problems were added for the first time.

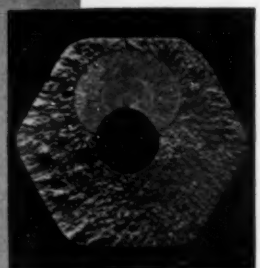
Before the 4-day show ended on May 16, attending coal industry men had viewed a display of the latest in mining machinery and equipment. Alert to the coal industry's continuing drive to modernize its mines and plants, manufactures had top technical men available to assist mine operators in solving mechanization problems.

(Continued on page 726)

First afternoon of the convention was reserved for attendance at the display of modern coal mining machinery.



SR—the new Sandvik Coromant treatment gives steels 50% longer life

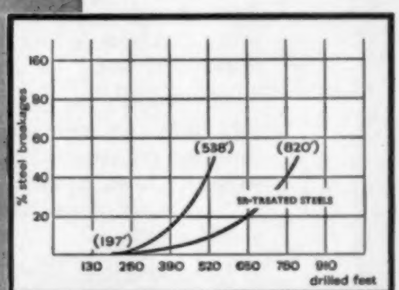


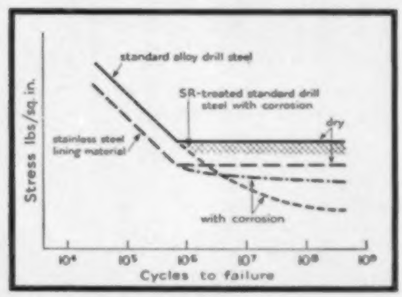
Corrosion invariably lessens the fatigue strength of drill steels and causes earlier breakages. The breakages start from corrosion craters and indentations, around which ever-widening areas of worn surfaces are formed. (See picture of cross-section.)

The main cause of corrosion is moisture—so effective protection of the steels against moisture during both storage and actual drilling eliminates corrosion and gives longer life to the steel. This protection is given to Coromant integral steels by the SR treatment, a new exclusive Sandvik feature.

PRACTICAL TESTS GIVE CONCLUSIVE PROOF

The diagram on the left shows clearly that SR-treated steel rods have a 30%-50% longer working life than those of untreated steels. Figures are based on extensive practical tests, which resulted in an average drilling depth of 820 ft. for SR-treated steels as against 530 ft. for untreated steels, before rod breakage.





HOW SR TREATMENT PREVENTS CORROSION

SR treatment is a new method of surface protection developed by Sandvik. It protects both the wall of the flushing hole and the outer walls from corrosion by a thin but strongly adhesive layer. The fatigue properties of the steels therefore correspond to those valid under dry conditions. On the wall of the centre hole, usually subjected to water flushing, the SR layer is everlasting, and *does not decrease the diameter of the flushing hole*. This is a distinct improvement on the old means of coating the centre hole with stainless steel, which lessens the diameter of the flushing hole, prevents full and effective flushing, and thus diminishes the drilling rate. Moreover, stainless steel has a lower fatigue strength than standard alloy drill steel.

Sandvik Coromant drill steels have been closely developed together with Atlas Copco rock drills. This drilling combination has for years been the most widely used in the world.

Sandvik Coromant integral steels, extension steels and detachable bits are supplied by Atlas Copco, who, in their own field, are the world's largest manufacturers of rock drills. For further information please contact: **U.S.**—Atlas Copco Pacific, Inc., 930 Brittan Avenue, San Carlos, California, Atlas Copco Eastern Inc., P.O. Box 2568, Paterson 25, N.J. **CANADA**—Atlas Copco Canada Limited, Montreal Airport, P.Q. **MEXICO**—Atlas Copco Mexicana S.A., Apartado Postal 56, Torreon, Coahuila.

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Flexibility plus!

NEW GARDNER-DENVER DELUXE "AIR TRAC"®

210° Swing

Hydraulic cylinder provides 120° swing, can be indexed for an additional 90° swing.

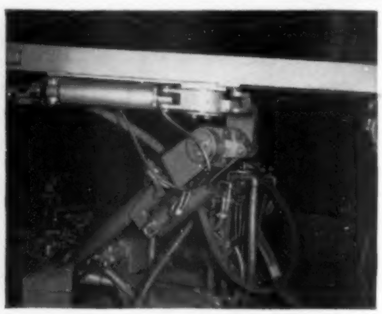
360° Dump

Hydraulic cylinder provides 90° dump, can be indexed a full 360°.

86° T-Bar Lift

Twin hydraulic cylinders provide T-bar lift of 86° 30′, from below horizontal to nearly vertical.

New Remote Control Panel and Driver's Seat—centralized controls provide instantaneous control of swing, dump, T-bar lift, crawler tracks and all drilling operations. Designed for convenience, comfort and safety. Saves minutes and reduces operator fatigue.



New DPAT Hydraulic Drill Positioner—this creep-free hydraulic system maintains alignment at all drilling angles and avoids stuck steel. Provides fast, effortless, power positioning for all vertical, horizontal and flat lifter hole spotting.

New Model G-2 Bit Grinder—this deluxe "Air Trac" extra saves time, too. No need to send back or wait for bits—you sharpen spare bits on the job. Plus new free-wheeling drive shaft design for towing "Air Trac" . . . tool box for tools, bit and coupling storage.

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(*Continued from page 722*)

Also attracted to the show were a large number of mining men from foreign countries, including Sweden, West Germany, England, Spain, Australia, and France, who are interested in the application of American methods and equipment to their own operations.

A sizeable number of mining representatives meet a sizeable dragline bucket in the Public Auditorium in Cleveland.

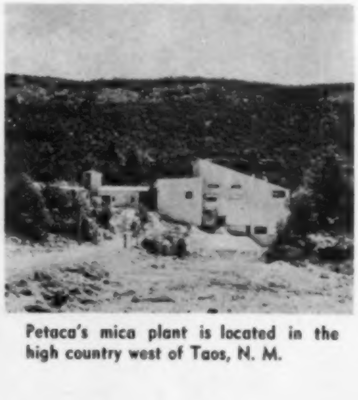
Petaca Air-Grinds Mica at 90 Tpd

Petaca Mining Co. of Sante Fe, N. M., this year expects to become the world's largest producer of ground mica. Petaca is one of four mica processors using compressed air for fine grinding.

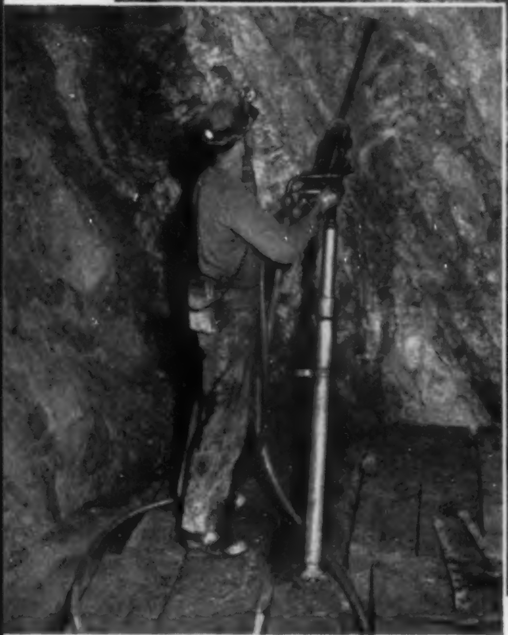
Mica is fed to a pulverizing and classification system at minus ½-in. and plus 18 mesh to produce closely controlled particle end-sizes.

The fluid energy mill system, a Majac Jet Pulverizer, impacts the mica against itself while it is entrained in two directly opposed, high velocity streams of air. The mica is then carried to a classification section which provides a closed circuit for regrinding oversize. The wet mica is dried by heat content and moisture-carrying capacity of the air.

The Petaca operation has a capacity of 90 tons of mica per 24-hr period. Air consumption of the pulverizer is 2500 cfm at 100 psig heated to 800°F.



Petaca's mica plant is located in the high country west of Taos, N. M.



H10AL Air Leg takes the hard work out of drilling —absorbs shock, advances the drill into the rock.

Operator can quickly and easily change position for bolting. Air Leg keeps drill in line with hole — reduces drill wear.

One Tool Handles Both Production and Rock Bolting

Le Roi H10AL Air Leg does double duty in typical stoping operation.

Recent design changes reduce wear, ease dismantling

Le Roi's H10AL Air Leg is shown here doing two jobs in a sphalerite stoping operation. Down at the 1900-foot level in a Montana mine, the operator uses both 6- and 11-foot steels while stoping. He makes an 11-foot advance per round in this horizontal breast cut and hydraulic fill stope.

After each blast, he scrapes and bolts the rock walls before drilling the next round. He doesn't need an extra tool. He merely changes the direction of his H10AL Air Leg to quickly and easily handle the rock bolting operation, too.

You can use Le Roi Air Legs as stopers, drifters, or sinkers. They have a full range of drill rotations. An exclusive 11-position feed control allows you to set and maintain any desired feed pressure from 9 psi to full line pressure. That makes it easy to keep lined-up with the hole — reduces front-end wear, eliminates rotation strain — keeps your drill-repair costs down.

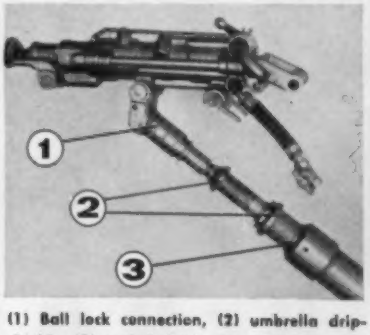
There's no third hose or clumsy "Y" connection. And the Air Leg absorbs the drill recoil. That means an easily handled rig — one that won't tire out the operator, lets him get in plenty of footage with less fatigue.

New Improvements

A sturdy ball-lock connection between drill and Air Leg on recent models permits quick dismantling for easy transportation. This unit is sealed against dirt, and is far stronger than the old bayonet-style construction.

Umbrella drip shields over both pistons keep out unwanted dirt and sludge. Bleed air at both pistons will carry oil to the cup leathers and also prevent dirt from entering the working parts at bushing and piston points. Other mechanical changes and improved metallurgy reduce wear from vibration throughout the entire feeding cycle.

You can choose from several types of Le Roi Air Legs having single or telescopic 3, 4, 5, or 6 ft. feeds. Conversion kits are available to convert older models to the new Le Roi design. Write today for complete information on this useful tool.



(1) Ball lock connection, (2) umbrella drip-shields, (3) sealed dirt-free construction.

WABCO

LE ROI Division of Westinghouse Air Brake Co., Milwaukee 1, Wisconsin, manufacturers of Newmatic air tools, Tractair,® portable and stationary air compressors, and heavy-duty industrial engines. Write us for information on any of these products.

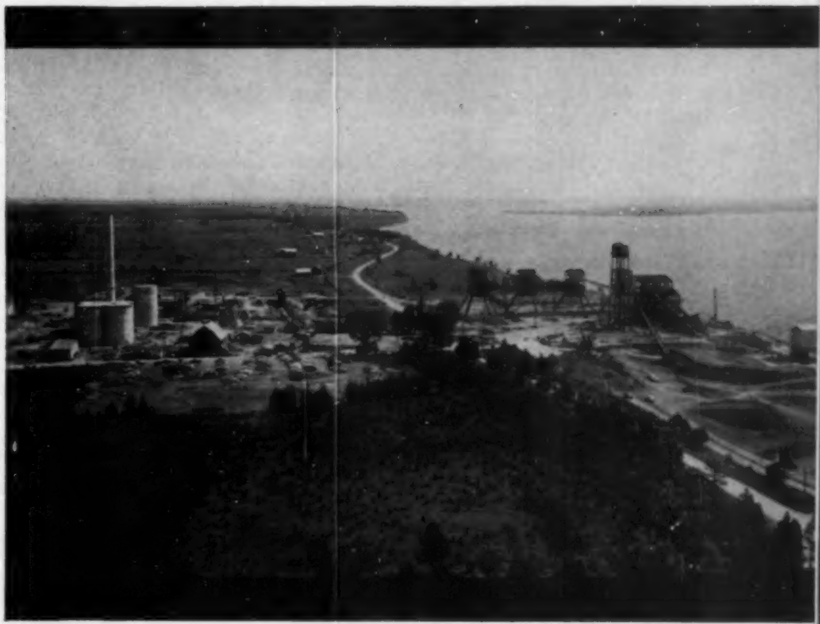
chosen for Heavy Duty Service at the plant of Lake Ontario Portland Cement Co. Picton, Ont., Canada

The new 5000 bbl. per day dry process cement plant of the Lake Ontario Portland Cement Co., combined with a modern 6000 ton per day aggregate plant, requires heavy duty primary crushing equipment to handle hard-to-crush rock.

The Kennedy No. 48 Gearless Gyratory Crusher is designed to handle large sizes of quarry rock regardless of hardness. Chosen by Lake Ontario Portland Cement Company as being best suited to meet the requirements of the combined operation.

In addition to 48 inch primary crusher Kennedy Gyratory secondary and tertiary crushers and impact crushers are installed in this modern plant.

Let K V S engineer help *you* select crushing equipment to meet any specific condition. Consultation, at any time.



Features which distinguish the KVS No. 48 Gyratory Crusher

- Primary Crusher
- Low-head Construction
- Gearless . . . Gyratory Type
- Synchronous Motor built directly into crusher pulley
- Power used only for crushing—no transmission loss
- All moving parts carried on roller bearings
- Produces peak capacities with minimum maintenance and operating cost

KENNEDY PRODUCTS

- Gyratory Crushers
- Swing Jaw Crushers
- Tube Mills
- Ball & Rod Mills
- Vibrating Screens
- Rock Feeders
- Air Swept Tube Mills
- Rotary Kilns
- Coolers, Dryers
- Preheaters, Deheaters
- Belts, Conveyors
- Pneumatic Transport Systems
- Complete Aggregate Processing Plants
- Waste Heat Boilers
- Pulverized Coal Firing Systems
- Asbestos Plants
- Complete Lime Plants
- Complete Cement Plants
- Steam Generators

MANUFACTURING & ENGINEERING CORPORATION

TWO PARK AVENUE, NEW YORK 16, N.Y. • FACTORY, DANVILLE, PA.

ATOMIC energy's burgeoning industry will spend more than $500 million in 1957 on uranium mining and beneficiation, instrument manufacture, construction of reactors, and research.

Speaking at the annual meeting of the American Iron & Steel Institute, L. L. Strauss, chairman of the Atomic Energy Commission, said that at least 21 U. S. companies are building or have contracted to build various types of reactors. Fifty-nine of these units are in various stages of development or completion for private concerns, the Federal Government, or for export.

During the last calendar year domestic firms made plans for or contracted to build eight uranium mills, a feed materials plant, five plants for the manufacture of fuel elements, and three for the production of vital metals such as beryllium and zirconium.

This year, Mr. Strauss said, some $270 million are slated for reactor construction, the largest expenditure; mining and milling outlay will amount to $200 million.

CORPORATE management is showing an increasing tendency to stay abreast of national economic trends and to take advantage of industry cycles by the use of economic forecasting, according to a survey by the American Management Assn.

By questioning a number of company presidents by mail and by making a detailed study of a variety of businesses in many fields, the survey also learned that most business organizations depend greatly on trade journals for economic forecasts. In some cases also, special research sections are provided within a company to study its specific outlook.

One point was stressed. Watch consumer buying power when making any forecasts on the trend of your branch of industry. In fact, watch its fluctuations even closer than the trend figures of your trade itself. Most companies do, whether they produce consumer goods, industrial goods, or services, according to survey findings.

ONE of the much encouraged but highly misleading statistics of our time says that the U. S. has an untapped pool of "100,000 highly-qualified high school graduates" who do not go to college only because they lack financial resources. A recent newsletter issued jointly by the Engineering Manpower Commission of Engineers Joint Council and the Scientific Manpower Commission notes that this number is being used as a basis for justifying a Federal scholarship program and other remedies for the short supply of engineers and scientists.

Their research led to the presumption that the statistic was derived from a recent comprehensive study, "Encouraging Scientific Talent," by C. C. Cole, Jr. The Cole book states: "Our estimate of the annual number of high ability high school graduates in the nation not now going to college for financial reasons, but who presumably could be won to higher education by means of scholarship programs, is between 60,000 and 100,000." These figures are derived from a projection of results of the National Study of High School Students and Their Plans, to the estimate of the number of highly qualified secondary school seniors of 1955. The study gleaned its data from 9000 of the approximately 365,000 such seniors that year. The newsletter in hand points out that through some process of "statistical alchemy," the carefully qualified estimates in the Cole report have been taken up without qualification as pure and incontrovertible fact.

To base preparations for future educational opportunities on the potential "100,000" students would be extreme optimism for a number of reasons. For example, almost 50 pct of the indicated number are girls. Ability notwithstanding, the tendency in general is to direct their interest to fields other than science and engineering; and no sudden turnabout can be expected. In addition, a number of the total, although they have registered high scores in examinations such as the Army General Classification Test (AGCT), may not have the necessary background in mathematics and science for technical education. On this matter Mr. Cole stated: "Many of these are probably lost to the scientific professions because they have not been stimulated or guided into taking college preparatory programs that included a minimum number of mathematics and science courses."

In addition he said: "It is probable that each year between 8000 and 15,000 male high school graduates with marked scientific talent could be retrieved if they could be found and provided with sufficient financial aid to enable them to go to college."

To provide excellent educational opportunities for deserving students is fine, but instead of shaping the facts to arrive at a figure like the "magic 100,000" it is better policy to analyze the situation as EMC and SMC have done. "If we are not more careful about our use of the results of competent social science research," they note, "we probably will find ourselves in a few years—perhaps sooner—rigging an educational pile driver to force a carpet tack into a sponge."

ALKALI metals are growing in importance daily and their most rapidly growing family member, lithium, has a potential of about a million pounds a year for 1970, according to M. Sittig of the American Lithium Institute. In the alkali family—lithium, sodium, potassium, rubidium, cesium, francium—francium is almost unknown, but rubidium and cesium are on the threshold of commercial availability as byproducts of lithium manufacture, says Mr. Sittig.

Speaking at the Reactive Metals Conference of the AIME, he said sodium, which is now produced at a quarter-billion pounds a year, indicates no prospect of a drop from its present price level of 16¢ to 17¢ per lb; potassium, on the other hand, could drop in price with an increase in production. But lithium, which is now a little more than $10 per lb, cannot be expected to drop to much less than $5 per lb because of the difficulty encountered in separating the metal from its ores. Lithium aluminum silicate ores must be chemically split by hot roasting processes, and a leach liquor then processed into the chloride. As in sodium processing, its fused chloride must then undergo electrolysis.

But the fields of metallurgy, catalysis, and propellant fuels all have alkali use possibilities to compensate production costs. In Mr. Sittig's opinion the opportunities for fruitful research on the alkali metals are virtually unlimited.

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NEW fuel, potentially useful in nuclear power reactors, has been developed by scientists at the Argonne National Laboratory. For the first time, Argonne is using ceramic pellets of urania-thoria (UO_2 and ThO_2) to produce reactor heat. The ceramics, unlike metallic fuel elements, do not grow and become distorted under intense irradiation. Some metallic elements have been known to double in length under certain conditions, and such physical changes may bring about radiation danger through mechanical failures.

Crystal studies of uranium show marked changes in size and structure of the crystal under irradiation. Rolling uranium metal tends to unify the crystals in a single direction; when a majority of the crystals lie in one direction the changes due to irradiation are enormously increased in that direction. Since ceramic crystals lie in all directions, the effect of irradiation on a ceramic element is much less than on one of metal.

As designed for use in Argonne's BORAX-IV boiling water reactor in Idaho, the ceramics are sintered and assembled in an aluminum high nickel covering. Their ability to withstand high temperatures has already been proven.

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ACTIVITIES of the Concentrate Procurement Division of the Atomic Energy Commission at Grand Junction, Colo., have increased in step with the growth of uranium mills and more qualified recruits are needed. The AEC wants graduate engineers with a minimum of four years' experience in design, construction, or operation of ore beneficiation or hydrometallurgical plants. Duties will involve the administration of mill contracts throughout the western states, and annual salary ranges $7035 to $10,065 depending on qualifications and experience. Applicants for this increasingly important work should submit a resume of education, experience, and personal history to the Personnel Office, U. S. Atomic Energy Commission, Grand Junction Operations Office, Grand Junction, Colo.

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RECOGNIZING the danger of maintaining copper at the 32¢ per lb basis which has been its latest stronghold, the copper industry had reduced the price of the red metal (at presstime) to 29¼¢—a low which has not been quoted by major producers since late March 1953. Zinc too has again been hit by a price reduction. The present loss is ½¢ per lb, bringing it to a 3-yr low of 10½¢.

Despite cutbacks in production, world copper output remains far in excess of consumption. The 2¾¢ drop may be attributed in part to a sudden downtrend of prices in Europe. London Metal Exchange quotations, reflecting recent reductions by the copper fields of the Belgian Congo and Northern Rhodesia, sagged to 27.8¢ on June 18. To maintain the difference between this price and the one tenaciously held by U. S. producers was to beg foreign fabricators to ship their products here for higher profit. The only answer was for the U. S. to follow the trend with a figure which better suited the depressed market.

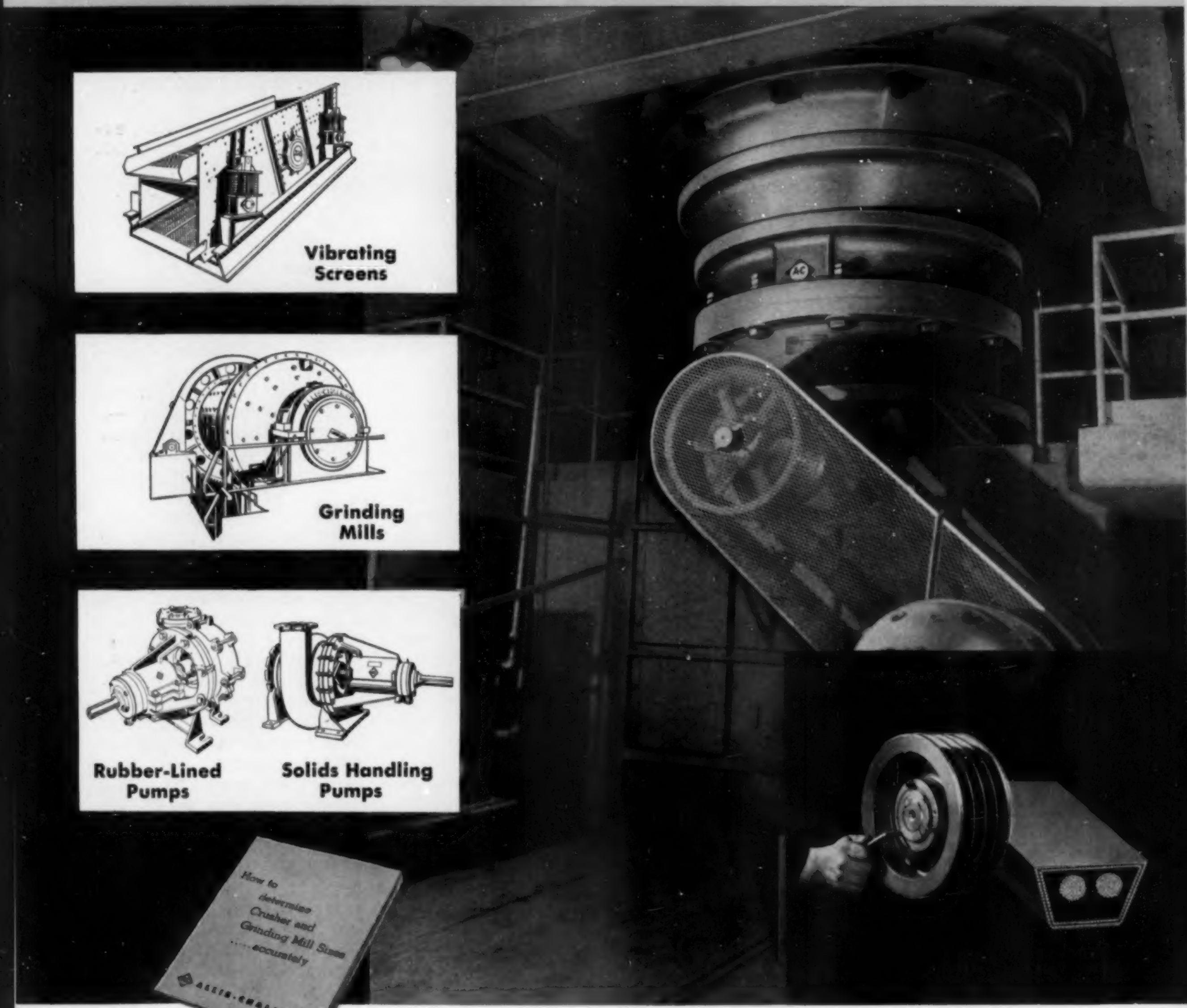
The zinc price drop is the fourth since early May, when the situation of oversupply was shown up sharply with the suspension of the government agriculture barter program.

The new barter program is seen to be impractical for solid support of the mining industry, and the strategic stockpile is heavy laden with material. Moreover, imports which have flooded the U. S. market of late have aggravated the situation created by generally cautious consumption in industry.

The long-range minerals program, which at this point is still in the debating stage, may provide a substitute for the present tariffs on lead and zinc. In part, the proposed measure involves a sliding scale import excise tax. This would become effective whenever prices declined far enough to hurt domestic producers and would be held off if prices should rise.

It does not cover all metals, however, and it is feared that the tax, which would be based on average prices for a three-month period, would encourage surge loads of foreign material whenever imposition of a higher tax was seen in the making. As the plan has evolved around zinc, the metal is hoped to be maintained at about 13½¢ per lb. Lead is expected to settle in a position around 16¢. In general the new long-range plan is viewed with uneasiness and in some camps it is violently opposed. It is not enough, but it is grudgingly admitted to be a step in the right direction.

HERE'S YOUR One Source...



Send for Bulletin 07R7995

"Work index" formula enables you to evaluate crushing and grinding operations . . . compare efficiency of plants, circuits, machines. This handy reference offers only scientific method of determining the right machine and required horsepower.

Gyratory Crushers

Emergency unloading, wear compensation, setting changer are flip-of-the-switch operations on Allis-Chalmers crushers equipped with *Hydroset* mechanism. Even the world's largest crusher utilizes the convenience and economy of the *Hydroset* mechanism.

Texrope Drives

For maximum efficiency in transmitting power between motor and machine, Allis-Chalmers offers a complete line of *Texrope* V-belt drive equipment . . . variable speed sheaves, fast adjusting motor bases, *Texrope* belts with 33% more gripping strength.

GET ALL THE FACTS. See your Allis-Chalmers representative or write Allis-Chalmers, Milwaukee 1, Wisconsin.

ALLIS-

One Responsibility

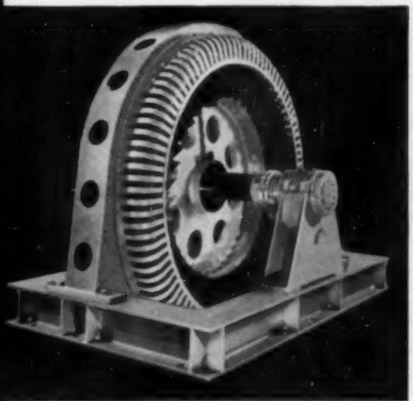
PROFIT PACKAGE

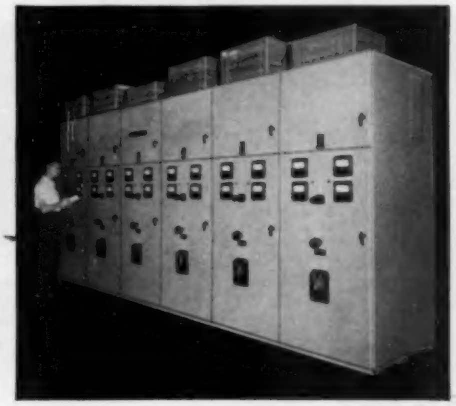
Processing Machinery, Pumps, Motors and Power Equipment Engineered to Work Together . . . Designed to HELP YOU Increase Production and Cut Costs

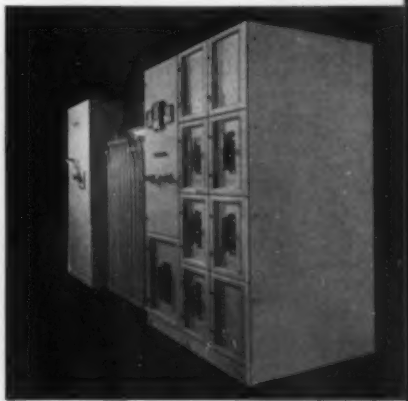
CRUSHERS, grinding mills, screens, pumps, generators, switchgear, transformers, motors, drives, control — *Allis-Chalmers builds them all.* And out of this unequalled diversity has come the unique ability to "coordineer" machinery and equipment for a complete process—yes, even for an entire plant.

How it Works

Allis-Chalmers maintains separate departments staffed by research, design, manufacturing and application specialists for each product. "Coordineering" results from an interdepartmental exchange of ideas and technical information correlated in *one department specializing in mining applications.* In this department components are matched to meet the requirements of your job. New as well as existing equipment in your plant is integrated into a smooth, productive, profitable operation. And, of course, Allis-Chalmers assumes undivided responsibility for efficient performance.







Motors

Allis-Chalmers builds a complete line of motors from ½ horsepower and up. Applying the "work index" formula, Allis-Chalmers engineers can help you determine the required power input and apply the right size motor needed for maximum efficiency and economy.

Control

Starter illustrated features circuit designed to cut crusher downtime. Overload protection is provided by two sets of thermal overload relays. One set operates on slight overload to sound warning. Second set stops motor when temperature reaches the danger point.

Unit Substations

Designed for maximum flexibility. Additions or replacements to basic centralized unit can be made conveniently at any time. Strategically located, unit substations bring high voltages near load centers — cut cable costs, minimize line loss, save space, provide complete protection.

Hydroset and Texrope are Allis-Chalmers trademar

CHALMERS

A-C ALLIS-CHALMERS

A-5406

Now available in S-D Automatics only 32" high!

To meet today's mechanization trends the S-D "Automatic" bottom dumping mine car with *overlapping ends* provides the ideal, practical answer to the question, "How can we obtain continuous loading of trips at loading points?"

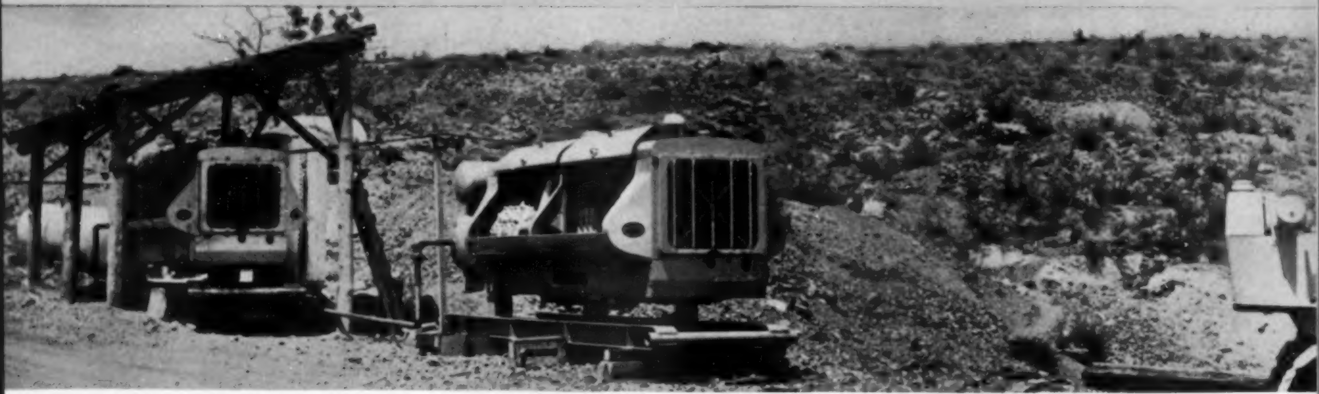
In addition to others and the S-D "Automatic" illustrated, we recently manufactured and shipped to a Kentucky mining company the same design car, but only 32" high, 6'8" in width, 19' center-to-center of couplers and having an inside body length of 16'. In addition to *overlapping ends*, you also obtain in S-D "Automatics," and only in S-D "Automatics": 1 — "Twin Safety Latches" for safe and sure latching . . . 2 — Cars that are Safety Sealed against dust leakage, and 3 — ¼ to ½ ton more capacity per car for the same overall dimensions! Write us today for complete information! *Sanford-Day Iron Works, Inc., Knoxville, Tennessee.*

Pictured below is a trip of S-D "Automatics" with Overlapping Ends in actual operation. The car above (and further illustrated at right and left) is one recently ordered by a large company. It is 7' in width, 44" high, 20' center-to-center of couplers with an inside body length of 16½ feet. It further features spring mounted trucks and automatic couplers.

SANFORD-DAY

Knoxville, Tennessee

AT THIS FAMOUS MINING SITE—
"PLENTY OF RELIABLE POWER"



This is the site of the "Bridal Chamber," where a solid chunk of nearly pure silver weighing an estimated six million ounces was discovered in the late nineteenth century. There is now a manganese mine and mill on the site at Lake Valley, New Mexico.

Two Caterpillar D13000s run 16 hours a day, providing all pneumatic power through Gardner-Denver compressors. The CAT* Diesels have needed no repairs. A third Cat, a D13000 Electric Set, supplies electric power for the manganese mill.

"Our three Caterpillar D13000 Engines supply our mining and milling operations with plenty of reliable power," says the mill superintendent for Haile Mines, Inc., of Hillsboro, N. M.

Now you can get the new Caterpillar D342, which replaces the D13000 in the Caterpillar line. Capable of 210 HP (maximum output capacity), the four-cycle D342 Diesel is built to do more work at lower cost with less down time than any other engine in its class. Like all other Caterpillar Engines, the D342 has such long-life features as "Hi-Electro" hardened crankshaft journals and cylinder liners, foul-free fuel injection, aluminum alloy bearings, and highly effective filters and seals to protect its built-in Caterpillar precision.

There is a full line of Caterpillar Diesels, up to 650 HP (maximum output capacity). Your Caterpillar Dealer will help you select the Cat Engine or Electric Set that's "tailor made" to do most work for you at lowest cost. Ask him for full facts and figures soon. And count on him whenever you need skilled service and parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

CATERPILLAR*

MODERN HEAVY-DUTY POWER

Know Your Society

Mining Engineers Name John C. Fox Secretary

EFFECTIVE July 1, John Cameron Fox became Secretary of the Society of Mining Engineers of AIME. Arnold Buzzalini, the former Secretary, resigned to return to private industry. A member of Institute since 1938, the incoming Secretary of the Society of Mining Engineers is well acquainted with members of the profession in every branch of the industry and brings to his new job a broad understanding of mineral industry operating and economic problems.

Since graduating from Columbia University School of Mines, Mr. Fox has held a variety of jobs in the mineral industry ranging from mine laborer to assistant manager of the mining division of a large mining company. These positions have taken him to all parts of the United States, to Latin America, and to Canada. He has been connected with underground and surface mining operations in gold, lead, zinc, copper, nickel, and coal.

Along the way, Mr. Fox spent four years teaching in the School of Mines at Columbia. He has also had extensive editorial experience, through work for the *Canadian Mining Journal, American Metal Market, Engineering and Mining Journal,* and as editor of *Mining Congress Journal* for five years.

In addition to his AIME affiliation, Mr. Fox is a member of the Columbia University Engineering School Alumni Association, the Mining Club of New York, and the Outdoor Writers Association of America.

VERSATILE BUCYRUS-ERIE STRIPPER WITH THE RIGHT CAPACITY AND REACH

A Bucyrus-Erie 88-B shovel strips overburden at a Minnesota iron mine. The machine is owned by the S. J. Groves Co., Minneapolis.

Whether *your* stripping operation requires a dragline, stripping shovel or a standard shovel, the Bucyrus-Erie 88-B offers the flexibility to do the job to your satisfaction.

With either of these three front ends, the 88-B puts more than 75 years of Bucyrus-Erie know-how on your job. It is a dependable, *basic* excavator — designed to function efficiently with whichever front end best fits your needs.

The 88-B's big diesel power plant, with your choice of torque converter or direct drive, provides plenty of power for the toughest digging and transmits it with high efficiency through the anti-friction bearings to the point of use. Its smooth, soft air controls permit easy, fast operation while retaining the "feel" of control for the operator.

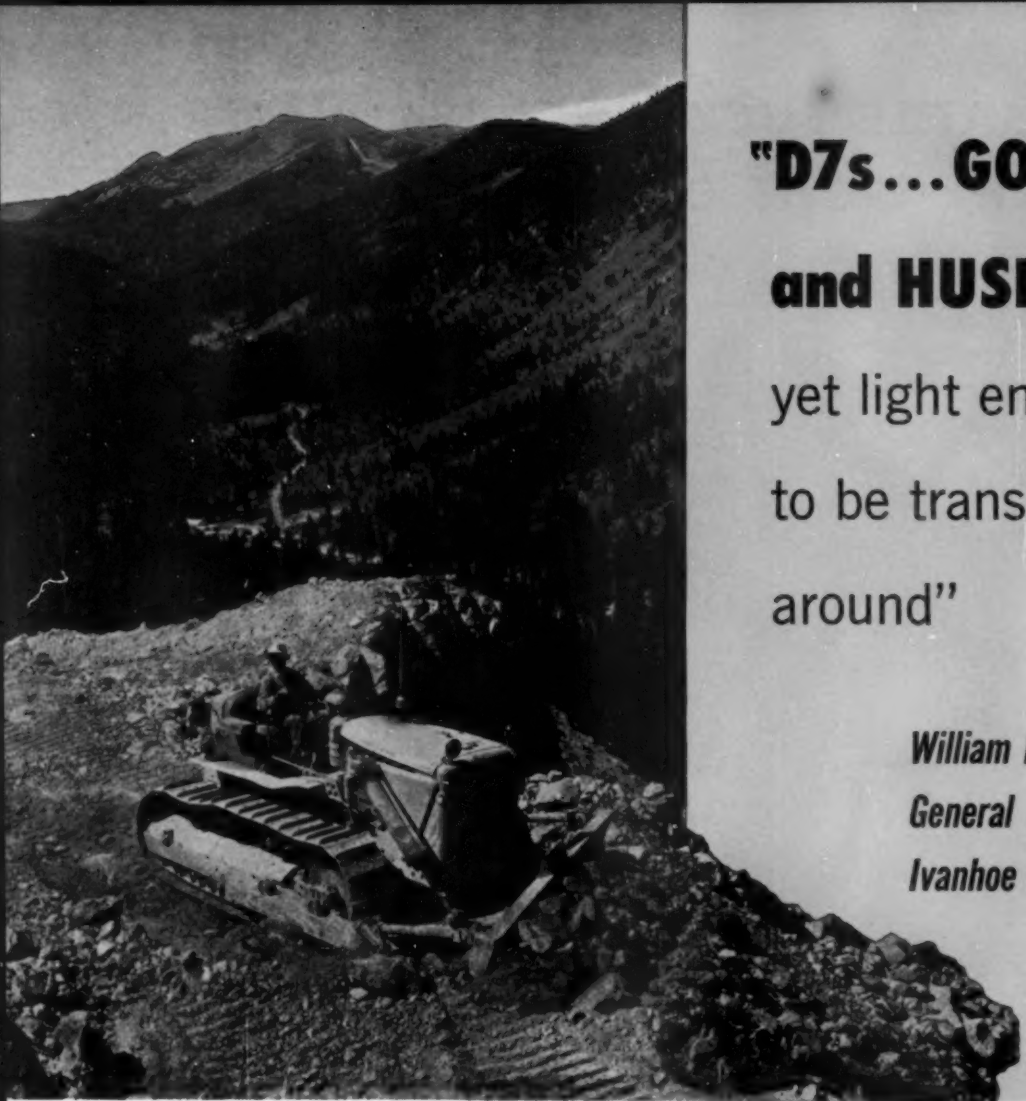
This outstanding stripping specialist is rated at 2 to 5 cubic yards as a dragline, 3 cubic yards as a stripping shovel and 4 cubic yards as a standard shovel. Take your choice and be secure with the knowledge that your stripper comes equipped with Bucyrus-Erie mining know-how.

369E57

Bonus Quality Specifications for molding and core sands are rigidly adhered to in the production of castings. Sand compositions must meet close specifications for permeability, moisture content, compression strength, and high-temperature properties. Here, a laboratory technician uses an electronic meter to determine the PH (acid-alkaline ratio) of the sand mixture.

BUCYRUS ERIE

SOUTH MILWAUKEE
WISCONSIN



"D7s...GOOD and HUSKY, yet light enough to be transported around"

William B. Tobey
General Superintendent
Ivanhoe Mine

Two durable CAT* D7 Tractors put in a full 16 hours of productive work each day at Ivanhoe Mine, near Glen, Montana. Here are some of the jobs assigned to these rugged workhorses:

ONE—They strip limestone overburden

TWO—They feed overburden to shovels

THREE—They clear large, granite boulders from ore

FOUR—They clean up ore after blasting

"The D7s," says William B. Tobey, general superintendent, "are good and husky, yet light enough to be transported around. They do a good job in the pit and in rock . . . they do better than any other type of equipment we could use."

Tungsten has been mined since 1952 at Ivanhoe Mine, owned and operated by the Montana Tungsten Division of Minerals Engineering Co. Production is about 850 tons of ore a day with a two-to-one ratio of overburden to ore. Elevation of the mine is 7,000 feet.

The D7 is designed to give you top production no matter what the climate, elevation, season or job. Rated at 128 HP (flywheel), its four-cycle diesel engine gives you a longer power stroke resulting in smoother, more efficient operation than in two-cycle engines. Fabricated steel steering clutch case and frame unit, hardened precise-machined transmission and final drive gears and the Caterpillar oil clutch make these tractors ideal for rugged mining duty.

Your Caterpillar Dealer backs every tractor with quick, efficient service and quality factory parts. Call him and name the date—he'll demonstrate on *your* job.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

WANTED—
THE HARD WORK

Mining History at Cornwall, Pa.

Bought for a nominal sum, the Cornwall property became one of the most valuable deposits in the U. S. Now this famous mine is nearing depletion.

by Robert G. Peets

After 216 years, the end of operations at the Cornwall mine can be foreseen within the next two decades.

The story starts in 1732 when three sons of Wiliam Penn—John, Thomas, and Richard—deeded 9669 acres in the Province of Pennsylvania to a Joseph Turner, who assigned it to William Allen. In 1734 Peter Grubb, who had prospected for iron in the area, paid Allen £135 for 300 acres of this tract in what is now Lebanon County. In 1737 he was granted a warrant for 142.5 additional acres, which included three hills of outcropping magnetite described as "rich and abundant, forty feet deep, commencing two feet under the earth's surface." This seemingly inexhaustible reserve was to become one of the most valuable deposits in the U. S. before the ore-rich Lake Superior region was developed.

R. G. PEETS is General Superintendent, Bethlehem Cornwall Corp., Cornwall, Pa.

In 1742 Peter Grubb built the Cornwall Furnace near the ore deposit, naming it after the English mining county where his father was born. Utilizing the local iron ore and charcoal made in the surrounding forest, the furnace operated continuously for 141 years, producing cannon, shot, and stoves and supplying the Continental Congress with much of its cannon and shell during the American Revolution. In 1777 Hessian prisoners put to work here were paid at the rate of 60¢ per day.

Maintained in almost its original condition, the Cornwall furnace still stands and can be seen under the direction of a State guide.

Following Peter Grubb's acquisition of the "ore banks," many others gained interests through purchase and inheritance until by 1864 there were 96 parts of ownership. In that year, to insure systematic and harmonious operation of the open pit mine, the various owners combined into the Cornwall Ore Banks Co. One exception was a small

Development continues across the entire orebody, but at least 80 ft is maintained between the area being drawn and the area being belled. The hanging wall caves readily to the surface on a plane about 65° from the level being drawn.

independent section known as the Robesonia Iron Co., which had been given the privilege for as long "as grass grows or water runs" to get free all the iron ore from Cornwall that was needed to keep one furnace going forever. Between 1916 and 1921, Bethlehem Steel Co. acquired entire ownership of the property by various purchases, except for the Robesonia reservation. Finally in 1926 Bethlehem Steel Co. purchased the interests of Robesonia Iron Co. and gained complete control of the area. Bethlehem's facilities for ore beneficiation were obtained in 1916 with the purchase of the Pennsylvania Steel Co. holdings in Lebanon, Pa.

Geology: The ore is a contact replacement type. Triassic intrusion of diabase trap rock into Cambro-Ordivician limestone resulted in the formation of many orebodies in eastern Pennsylvania. High grade iron-bearing solutions coming from or through the trap rock sill caused replacement of the limestone at its contact with the upper side of the trap rock intrusion.

There are two major orebodies in Cornwall. One of these outcropped and thus was the one originally located and mined by Peter Grubb. The top of the second orebody, farther east, was 150 ft below surface and was not located until 1919. As early as 1908 Arthur C. Spencer, writing about the Cornwall area for the U. S. Geological Survey, stated: "All of this ground, as far as the road leading from Rexmont to Overlook, is regarded as likely to contain a continuation of the Cornwall ore bed and to warrant such expenditure as would be required to prospect it adequately. To summarize, it seems that exploration should be extended along the strike of the deposit for about 1,000 feet toward the west and for 5,000 feet toward the east." However, nothing was done until 1919, when a dip needle survey readily located the additional ore occurrence.

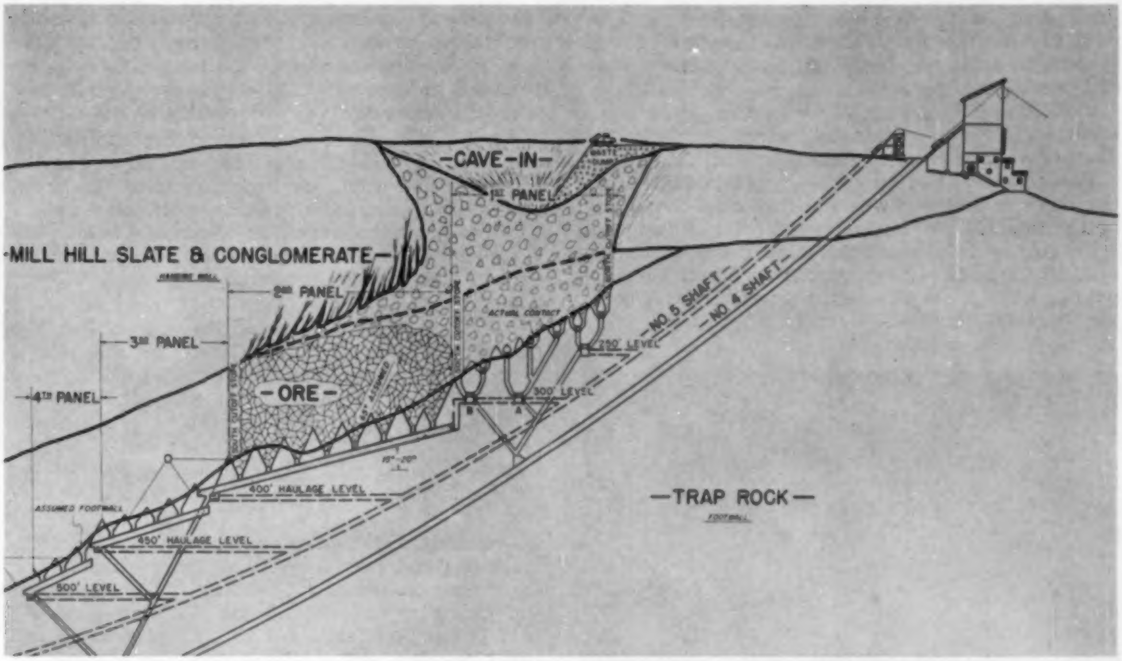
The ore consists of magnetite with the sulfides pyrite and chalcopyrite. It is unique in that it carries recoverable copper, gold, silver, cobalt, and sulfur. The gold and silver apparently are carried in solid solution in the chalcopyrite, and cobalt occurs similarly in the pyrite.

Open Pit Mining: Prior to 1900 open pit mining was carried on by the old *wheel and bench* method, which consisted of working the ore in benches or steps 16 to 20 ft deep and hauling it to cars in wheel barrows. Eventually Bucyrus-Erie and Marion steamshovels were placed in the pit, loading into railroad cars hauled out by steam locomotives. As competition developed from Lake Superior ore and blast furnace requirements became more stringent, further changes were needed to continue an economic operation. Accordingly, in 1910, a 45° skip hoisting incline was built on the footwall side of the pit, eliminating long, steep rail haul. A screening and crushing plant was built to eliminate hand sorting.

Except that electric shovels replaced the steamshovels, this method was continued until 1944, when the depth of the pit was carried so far below the bottom of the incline that the rail haulage grade was again too steep and long. The steam locomotives were replaced by six 30-ton diesel side-dump trucks, which allowed the dumping arrangement formerly used for the railroad cars.

The first mining was in the outcrop, but since the orebody lies at a 30° slope and is overlain with limestone, it was necessary to start stripping in 1903. In 1944 economic limits of stripping were reached. By 1953 all the available exposed ore was removed and it was necessary to convert to underground methods entirely. This ended an operation that had produced more than 65 million tons of iron ore and made Pennsylvania the leading iron producing state for many years.

No. 3 Underground Mine: In 1921 a three-compartment incline shaft was sunk in the footwall near the west end of the open pit to mine the lower extremity of the orebody. Near the collar a com-



No. 4 mine is serviced by two inclined shafts, Nos. 4 and 5, sunk 200 ft in the trap rock footwall about 100 ft below the ore-trap contact. The slope at the collar is 36°, flattening to 26° at the bottom. Each shaft is 20 ft wide and 7 ft high with three compartments, two skipways, and a manway.

plete mine plant was constructed for crushing, screening, cobbing, and loading.

The method first employed was sublevel stoping. This was changed in 1926 to a room or shrinkage stope and pillar method. Rooms 15 ft wide with 10-ft pillars between were shrinkage mined from footwall to hanging wall. The pillars between the stopes were drilled and blasted progressively as the stope was mined upward.

In 1940 this mine was closed down so that ore still available to the cheaper open pit mining would not be disturbed. When the open pit was completed in 1953 underground mining was resumed, but this time it was decided to use a block caving method that had proved highly successful at the other underground mine. Caving has been started in several areas. From the edge of the old open pit the caving action taking place along the pit wall can now be seen. Production is limited to 2200 tpd by the single shaft, which hoists men, material, and ore. A second smaller entry into the mine is used only for ventilation and passageway.

No. 4 Underground Mine: In 1926 development was begun on the kidney-shaped orebody of No. 4 mine located by geophysical work in 1919. In 1927 and 1928 two parallel incline shafts were sunk 200 ft apart in the trap rock footwall underneath the orebody. These shafts, initially sunk only to the 700 level, have three compartments each and are catenary curved; one is used for hoisting men and materials and the other for ore. The work was accomplished by sinking the ore shaft full width, drifting over to the other shaft location on three levels, and then raising the second shaft. The pilot raise was then slabbed to size by starting at surface and working the blasted rock downslope with a scraper. Shaft steel and track were installed as the slabbing progressed.

The business depression in 1929 occurred just as development was getting under way, and in 1931 the mine was allowed to fill with water. It was dewatered in 1936 and mining was resumed in 1937.

The structurally weak ore was recognized as amenable to block caving, which was started at one limit of the orebody, retreating across to the other end. Development work, all located in the footwall, consisted of driving haulage and grizzly levels with connecting transfer raises and undercutting bells.

Mine development was started on the 250 level. Shortly afterward the pattern was changed from the breaking sub and transfer raise layout to the scraping drift method still in use.

Subsidence to the surface did not occur until a 170x415-ft area had been mined. The steadily increasing size of the opening caused the operators much concern, and two churn drillholes were drilled from the surface above the opening and blasted. A few days later the subsidence started. It has progressed well ever since.

By 1945 mining had reached the 700 level and it became necessary to extend the two shafts to the 1225 level, which is the depth limit of the ore.

Production in 1940 amounted to 358,000 tons, gradually increasing to the 1.1 million tons per year now being hoisted. Five notable factors have contributed to this growing efficiency:

1) The block caving method was converted from a system using breaking sub, transfer raises, and car loading chutes to one embodying slusher drifts through which the ore is drawn from the bells and scraped directly into the cars.

2) Skip loading pockets were changed from branched raises with loading gates at the bottom to scraping trench pockets.

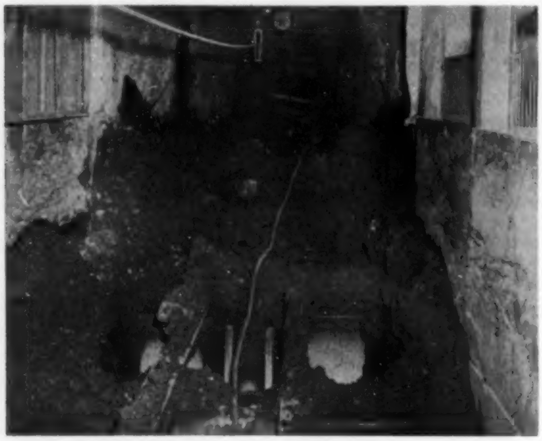
3) Timber support originally used was converted to solid concrete arched lining. Now the yieldable

steel arch sets are showing excellent results.

4) Cleanup of the tremendous amount of wet spillage in drifts has been mechanized with the use of track cleaning machines.

5) Shaft spillage at the skip loading pockets has been controlled by spillage collection pits under the pockets which can be cleaned with slushers.

Concentrator: During the early years of production high grade ore was mined, some containing better than 60 pct Fe and very little copper and sulfur. After 100 years these high grade ores were used up, and the mine produced an ore of 45 to 50 pct Fe, with 2 pct S and 0.3 pct Cu. Hand sorting increased the grade by 2 or 3 pct.



TOP: The scraping-type pocket consists of a scraping trench 90 ft long into which separate raises feed from each of the three levels above. MIDDLE: Mine pump discharge settling ponds. BOTTOM: Ore loading and stockpiling plants.

Placing the ore on a pile of burning wood finally eliminated the sulfur. This crude method soon gave way to roasting ovens, but until sintering was introduced the fines—which were higher in iron content than the lumps—proved difficult to roast.

As the high grade ores neared depletion it became apparent as early as 1883 that some form of concentration would be necessary, and the problem became even more pressing when Lake Superior ores reached the market. Thomas Edison's experiments on magnetic separation were among the early studies to find a solution.

In 1905 the Pennsylvania Steel Co. built a concentrator in Lebanon—a wet mill equipped with the Grondal magnetic separator. Beginning the following year, the concentrates were nodulized in three 7x100-ft kilns, which produced 400 tpd. In 1907 a Wilfley table was added to recover nonmagnetic pyrite and chalcopyrite concentrates, and in 1912 an Elmore vacuum oil flotation machine was started for the flotation of chalcopyrite, but with little success.

Acquiring the plant from Pennsylvania Steel Co. in 1916, Bethlehem Steel began an expansion and modernization program, adding mill equipment and providing six Greenawalt sintering pans. By 1918 production reached 1500 tons of nodules and sinter per day, and six more sinter pans increased sinter capacity to 2400 tpd by 1922. Nodulizing was discontinued in 1920.

The original six sintering pans were ultimately replaced by two single units embodying the high vacuum principle. Concurrent with developments for agglomerating finely ground magnetic taconite concentrates in Minnesota, pelletizing experiments with a shaft furnace were conducted in the Lebanon Raw Materials Research Laboratory. In 1950 first commercial pelletizing furnace in the U. S. was placed in operation near the sintering plant. Two more furnaces were added in 1953. Present production amounts to 1600 tons of sinter and 1100 tons of pellets per day.

Since the Wilfley tables and Elmore vacuum oil machines had not been successful in concentrating the chalcopyrite, experimental tests were carried out with oil flotation, and in 1919 minerals separation machines were installed. This marked the achievement of copper concentrates recovery. Further flotation plant improvements were made in 1927 with the addition of three regrind ball mills and six more flotation machines.

Another turning point occurred in 1940 when successful flotation of pyrite was started. This was of the utmost importance because the pyrite carried recoverable cobalt. From that time until very recently Cornwall ore accounted for nearly all U. S. cobalt production.

Invariably visitors to the Cornwall operations ask why the concentrator is nearly six miles from the mines. The answer is that although many proprietors were obtaining ore from the mines in 1900, only Pennsylvania Steel Co. built a concentrator, locating it in North Lebanon next to the company's blast furnace. Furthermore, other proprietors were not permitted to use the Grondal magnetic separator, since Pennsylvania Steel Co. had the American rights. The blast furnaces have long since been dismantled, and the expense of relocating the plant was not warranted by the remaining reserves of the mines.

Emery

- Nature
- Occurrence
- Uses

by Gerald M. Friedman

CONVENTIONAL usage defines emery as a natural aggregate of corundum and magnetite. Because emery bodies contain abundant spinel two types are recognized, spinel-bearing and spinel-free. Watson and Steiger[1] introduced the name *spinellite* for emery in which spinel is a major constituent, but this term has not been generally adopted.

Spinel emery grades locally into spinel magnetite rocks with or without accessory corundum. Even this variety has been used commercially in the past. The term *emery* therefore applies to natural aggregates composed of corundum and magnetite; corundum, magnetite, and spinel; and spinel and magnetite.

In Cortlandt Township, N. Y., the only area in the U. S. where emery has been mined during the past 30 years, the miners recognize two varieties, gray and black. The black emery fits the conventional definition, whereas gray emery is a cordierite-sillimanite and sillimanite-sapphirine rock of varying magnetite content. Production now comes entirely from gray emery. Since the end of World War II, perhaps even before, black emery has not been quarried in the U. S.

Occurrence: Although they are distributed throughout the world, emery deposits are rare. Before emery was discovered in Turkey in 1847, the world's entire supply came from the island of Naxos in the Greek Archipelago, one of the largest of all deposits. The term itself is derived from Cape Emeri, which is located on Naxos. The emery deposits of Turkey, Naxos, and the Kyzul-Kumy desert of Russia occur as lenticular masses in limestone.

American deposits were discovered in the second half of the 19th century. In the U. S. black spinel emery occurs along the Appalachian belt in New York, Virginia, and North Carolina; black emery lacking spinel has been mined in Massachusetts. The gray emery is commercially exploited only at Cortlandt Township, Westchester County, N. Y., although a rock of similar type is suspected to occur at Whittles, Va., where black emery was quarried from about 1917 until 1928.

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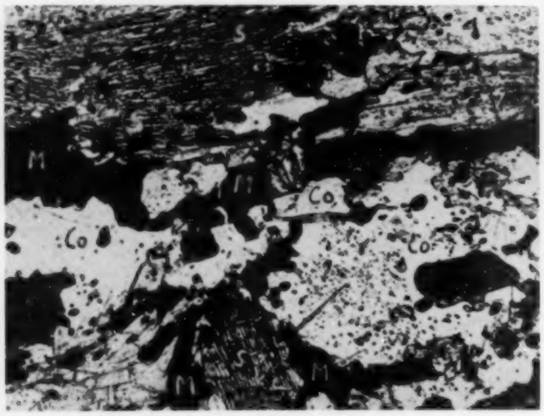
Chemical Analysis of Black and Gray Emery (New York)

Element	Black Emery, Pct	Gray Emery, Pct
SiO_2	0.84*	24.60
Al_2O_3	59.22	41.10
Fe_2O_3	16.66	25.36
FeO	14.02	
MgO	3.54	3.12
CaO	trace	2.55
Na_2O	trace	—
K_2O	trace	—
H_2O+	2.65	0.15
H_2O-	0.05	
TiO_2	3.28	2.22
P_2O_5	trace	—
S	0.06	—
Cr_2O_3	trace	—
MnO	0.06	—
Total	100.36	99.10

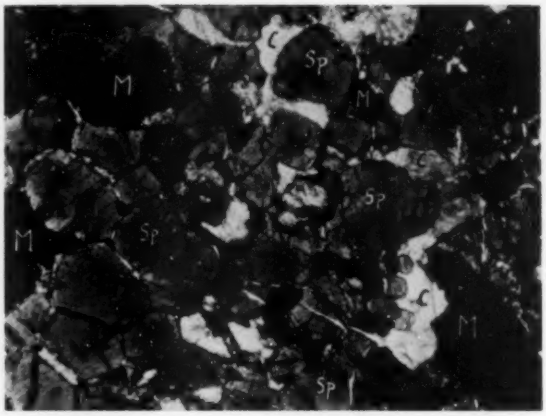
Analyst, black emery, G. S. Rogers (Ref. 4, p. 64). Analyst, gray emery, N. J. Federici.
* Probably derived from agate mortar.

Black emery deposits in the U. S. are confined to basic igneous rocks or their alteration products. They occur as irregularly shaped, usually lenticular replacement bodies in norites, gabbros, amphibolites, and probably peridotites. The gray emery of Cortlandt Township is a replacement product of the Manhattan quartz-mica schist, which has been affected by the contact metasomatism of a basic intrusive, the Cortlandt Complex. The emery deposits are confined to the contact aureole or to structural highs within the Complex.

Mineralogy and Chemical Composition: A number of authors have summarized in detail the mineralogy



Micrograph of gray emery showing cordierite (Co), sillimanite (s), and magnetite (M). X40.



Micrograph of spinel emery showing characteristic aggregate of spinel (Sp), corundum (C), and magnetite (M). X80.

of black emery in Massachusetts,[2, 3] New York,[4-9] Virginia,[1, 6-11] and Macon County, North Carolina.[5, 9] Others have described Turkish,[12-15] Naxos,[16] and Russian emery,[17, 18] and some of the German deposits.[19, 20]

Emery found in Massachusetts is a corundum-magnetite rock, whereas the emery of New York, Virginia, and Macon County in North Carolina is composed of corundum, titaniferous magnetite, and spinel. Ilmenite, hematite, pyrite, sillimanite, cordierite, andalusite, staurolite, and garnet are among the accessory minerals. Hoegbomite is common in both the Virginia and North Carolina emery.

The mineralogical composition of the gray emery is variable. Two types are mined, a cordierite-sillimanite rock with varying amounts of magnetite and a sillimanite-sapphirine rock carrying magnetite. The gray emery deposits at Cortlandt Township, N. Y., are zoned. The zone adjacent to the norite is commonly a sillimanite-sapphirine-magnetite rock, containing an estimated 45 pct sillimanite, 40 pct sapphirine, and 15 pct magnetite. The next zone may be formed by a cordierite-sillimanite-magnetite rock with the following estimated mineral percentages: 50 pct cordierite, 25 pct sillimanite, 15 pct magnetite, 9 pct sapphirine, and 1 pct mica. Accessory minerals are corundum, spinel, hoegbomite, and zircon. Locally labradorite feldspar has been noted. Gray emery is a dense, tough, heavy rock of about 7¼ hardness.

Metamorphic rocks of the following mineralogical composition locally adjoin the gray emery: sillimanite; kyanite; staurolite; garnet rocks with small amounts of magnetite, cordierite, mica, and chlorite; and kyanite, cordierite, garnet, staurolite rocks with magnetite, sodic hornblende, biotite, plagioclase, and sillimanite.

Black spinel emery is a rock composed essentially of iron, magnesium, and aluminum oxides and is devoid of silica. Gray emery is an iron, magnesium, aluminum silicate.

Preparation and Uses: Gray emery is tough, nonabsorbent, nonbrittle, and resistant to heat and abrasion. It is used chiefly as an additive to surfaces of heavy duty concrete floors to provide a nonslip, smooth surface that can stand the pounding of modern industrial uses and traffic.

Emery rock is crushed and transported to a series of vibrating screens, where the material is separated into four standard sizes: ⅜ in., ¼ in., type 20 (⅛ to 1/10 in.), and fines (<1/10 in.). The four sizes are then mixed proportionately and packaged in 100-lb bags for shipment. When applied for heavy duty flooring the rock is mixed with cement and spread to a depth of ¾ in.

References

1 T. L. Watson and T. L. Steiger: Titanium-Bearing Corundum Spinellite; (Rock-Emery); a Preliminary Statement of Its Occurrence and Composition in Virginia. Washington Academy of Science *Journal*, 1918, vol. 18, pp. 665-676.

2 B. K. Emerson: Geology of Old Hampshire County, Massachusetts. *USGS Monogram* 29, 1898.

3 B. K. Emerson: Geology of Massachusetts and Rhode Island. *USGS Bull.* 597, 1917.

4 G. S. Rogers: Geology of the Cortlandt Series and Its Emery Deposits. New York Academy of Science, *Annals*, 1911, vol. 21, pp. 11-86.

5 J. L. Gillson and J. E. A. Kania: Genesis of the Emery Deposits Near Peekskill, N. Y. *Economic Geology*, 1930, vol. 25, pp. 506-527.

6 J. W. Butler: Origin of the Emery Deposits Near Peekskill, N. Y. *American Mineralogist*, 1936, vol. 21, pp. 537-574.

7 G. M. Friedman: Sapphirine Occurrence of Cortlandt, New York. *American Mineralogist*, 1952, vol. 37, pp. 244-249.

8 G. M. Friedman: Study of Hoegbomite. *American Mineralogist*, 1952, vol. 37, pp. 600-608.

9 G. M. Friedman: The Origin of Spinel-Emery Deposits with Particular Reference to those of the Cortlandt Complex, N. Y. New York State Museum *Bull. 351*, 1956.

10 T. L. Watson: A Contribution to the Geology of the Virginia Emery Deposits. *Economic Geology*, 1923, vol. 18, pp. 53-76.

11 T. L. Watson: Hoegbomite from Virginia. *American Mineralogist*, 1925, vol. 10, pp. 1-9.

12 R. Kraemer: *Kleinasiatische Schmirgelvorkommnisse*. Inaug.-Diss. Leipzig, 1907.

13 H. Mueller and G. Berg: Ueber Magnetiteisenerz- und Schmirgellagerstaetten im suedwestlichen Kleinasien. *Zeitschr. f. prakt. Geol.*, vol. 24, pp. 11-16.

14 J. de Lapparent: Composition mineralogique, structure et origine des emeris de Turquie. *C. R.*, 1946, vol. 223, pp. 227-228.

15 T. S. Oenay: Ueber die Schmirgellagerstaetten SW-Anatoliens. *Schweizer. min. pet. Mitt.*, 1949, vol. 29, pp. 357-490.

16 S. Papavasiliou: Die Schmirgellagerstaetten von Naxos nebst denjenigen von Iraklia und Sikinos. *Zeitschr. Deutsch. Geol. Ges.*, 1914, vol. 65, pp. 1-123.

17 K. Ozerov: The Emery Deposits of Irtash Region, Ural Province. *Trans.*, United Geological Prospecting Service U.S.S.R., Leningrad, 1933, vol. 246.

18 A. F. Sodedko: On the Genesis of the Tamda Emery Deposits. Akad. Nauk U.S.S.R., *C.R. (Dokl.)*, 1939, vol. 25, No. 6, pp. 493-495.

19 G. Klemm: Ueber das Schmirgelvorkommen von Frankenstein zu Darmstadt. *Notizbl. d. Ver. f. Erdk. v. d. Grossh. geol. Landesanst.* Darmstadt, 1907.

20 G. Klemm: Die Korundfuehrenden Hornfelse und die Schmirgelgesteine von Laudenau und Klein-Gumpen bei Reichelsheim im Odenwald und ihre Nebengesteine. *Notizbl. d. Ver. f. Erdk. v. d. Grossh. geol. Landesanst.* Darmstadt, 1916, 5th series, pp. 23-41.

21 E. S. Dana: *System of Mineralogy*, 6th ed. John Wiley & Sons, New York, 1892.

22 F. P. King: A Preliminary Report on the Corundum Deposits of Georgia. Geological Survey of Georgia, 1894, *Bull.* 2.

23 R. B. Ladoo: Abrasives. *Industrial Minerals and Rocks*. AIME, New York, 1949.

24 J. H. Pratt: Corundum and Its Occurrence and Distribution in the United States. *USGS Bull. No. 269*, 1906.

25 J. H. Pratt and J. V. Lewis: Corundum and Peridotites of Western North Carolina. North Carolina Geological Survey, 1905, vol. 1.

Administration of Geologic Personnel

by Arthur E. Granger

An administrative geologist should be chosen first for his ability as an administrator and secondly for his professional ability.

IN the early days of the science, and until the recent past, geologists worked as individuals or in small groups. Prior to 1930 perhaps the largest single group under one administrative head was the Geologic Branch (now Division) of the U. S. Geological Survey, which employed at that time (including temporary help) 100 to 150 geologists. Today that same unit employs some 1500. In industry some companies employ as many as 100 geologists in a single department. These numbers obviously pose a need for administration. The basic qualifications for good administration are the same for any group of human beings, but the administration of geologists presents some special problems.

Choosing Administrative Personnel: There are two kinds of personnel needs: 1) technical, which requires professional geologists who have proved their capabilities in the field, and 2) clerical and fiscal, which provide the necessary supporting or *housekeeping* functions. This discussion will be concerned only with the first category, except to point out the need for competent and understanding help from clerical and fiscal people and close relationship between top administration, technical or professional personnel, and the clerical and fiscal groups.

An administrative geologist should be chosen first for his ability as an administrator and secondly for his professional ability, although his background and accomplishments in geology must be better than average. The ultimate, of course, is to have a person who excels in both. Most geologists are poor at administrative tasks and are generally resentful of them because they interfere with geologic pursuits. Nevertheless, because of the increasing numbers of personnel and the complexity of geologic work, someone must take the reins and function as both an administrative and scientific leader. The problems of obtaining large sums of money necessary to accomplish geologic objectives are also becoming increasingly complex, whether it be in industry, government, or academic areas; and administrative direction is necessary to get this monetary support.

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Administrators should not be selected on the basis of seniority or professional capabilities alone, but rather for their abilities: 1) to understand the individual's problems, both professional and personal; 2) to place people where they will function for the greatest good of the organization; 3) to get people to work as a team; 4) to be able to bridge the gap between management and scientific personnel; 5) to evaluate, reward, and guide people through their careers impersonally; and 6) to be able to plan and execute a geologic program that will successfully accomplish the results for which money and time are allotted.

Basic Qualifications for Administration of Personnel: An administrator who has been selected on the basis of these qualifications must develop the following minimum basic traits of a good executive of scientific personnel:

1) An ability to keep himself informed of the important elements of all operations.

This depends in large part on the number of personnel involved and the ability of the administrator of large groups to make personal contacts. From large groups, he must be able to obtain written reports that are informative but not voluminous. He must also be able to interpret the reports through personal knowledge of the problem and of the per-

son writing them. It is not practical for an executive to set himself up in an ivory tower, surround himself with lieutenants of delegated authority, and never attempt to contact any personnel below the supervisory level.

An administrator should never allow himself to become such a slave to protocol and paper work that he cannot devote some time to personal contacts with all his workers. For example, the writer was once asked to discharge a man who had been on the staff for more than a year. Since he was in an isolated field job, there had never been time for more than an introduction. A review of the immediate supervisor's reports revealed that the supervisory personnel had not fulfilled their duties in that they had never discussed the man's alleged shortcomings with him until they decided he should be fired. The writer had not fulfilled his duties as chief geologist by becoming better acquainted with the man and more familiar with his duties. The man was assigned to the main office where he could be observed personally, and while there he was told that his work had not been satisfactory and why. It turned out to be the case of the square peg in a round hole. In the office job he did so well that everyone agreed he should not only be kept but advanced.

2) The ability to switch mentally from one complex problem to another and come up with sound decisions.

The ability to make quick decisions and mental switches is particularly necessary. The supervisor should not make snap decisions but should train his men to present each problem so that the critical points are clearly brought out and briefly stated. The supervisor should then be able to grasp the problem quickly, tie it into the overall picture, and make a decision. In some cases decisions must be deferred, but whenever possible, personnel should not be held in indecision. Morale is always higher when people know definitely what is expected whether or not the decision is the one they desire.

3) He must have ready accessibility to all employes and avail himself of this.

4) He must have the perspective of overall plans and the ability to handle efficiently both routine problems and major ones in their proper degree.

5) He must have the ability to pick staff assistants who complement him to make an administrative team with broad technical and human understanding.

In choosing his assistants an administrator or chief geologist should look for the same qualifications previously mentioned, since in most cases the assistants are prospective chiefs. However, this is not always true. Some people may be exceptional as second in command but that may be their inherent ultimate level, and they may never develop to the point where they can take over all the responsibilities of a department head. In choosing his staff the administrator must always be on guard against those who curry favor by any means other than actual demonstration of their abilities. He must be aware of the feelings of others toward his staff assistants and himself as well. Both he and a good majority of the crew must feel that whoever is chosen can do the job efficiently and deserves it.

6) He must be able to carry out such unpleasant tasks as reprimanding second-rate work; making promotions on merit, sometimes passing by others with more seniority; and turning down projects without alienating or discouraging personnel involved. A good administrator will always remember that the ultimate responsibility is his and should not be passed off to subordinates.

7) He must be able to recognize when his employes are doing poor work because of personal problems.

8) He must be a champion of the individual freedom of each member of his group, yet it is essential that he have an acute sense of responsibility to the group as a team.

To champion individual freedom means that he must never allow an organization in which only the bosses are heard. Everyone in a scientific organization should be allowed to express his views directly to the chief if he cannot get satisfaction from his immediate supervisor. On the other hand, the chief should never take action after hearing any individual until the intervening supervisors are informed and also heard. The individual geologist must always feel free and encouraged to develop ideas and to know that his ideas will get a hearing.

9) To avoid becoming excessively involved in details, he must have the ability to delegate authority and responsibility and he must accept ultimate responsibility for the activities of his group.

10) He must see that those who produce the proper products receive credit and recognition be-

ABOVE: ***Bull pen*** **type of office space wastes time and money. BELOW: This same space, partitioned into small offices, helps to increase productivity.**

yond the administrator or executive. The practice of executives in listing themselves as coauthors of reports in which they have not participated is dishonest.

11) An administrator must never be jealous of the capabilities of a subordinate.

Good men should receive recognition and be brought to the attention of other and higher administrators. To produce a good man from his own group and advance him to greater things will never hurt an administrator of geologists, but rather will increase his own stature.

Relationship to Management: The qualifications above apply mostly to the relationship with personnel under the supervision of the administrator. Equally important are items that apply to the relationships of the administrative geologist with management. In fact, the primary responsibility of an administrator is to management, to turn out successfully for them the product for which funds, men and material are being expended.

1) He must inform management as to what geologic personnel can and cannot do for the company or public group and then present a well organized, realistic plan within the capabilities of his personnel and do his best to make it work. He must not accept any program that is scientifically unsound or beyond the capabilities of his personnel unless he clearly, and in written records, points out the fallacies of the management's request.

The education of management is of critical importance. Often a company has hired a geologic staff and expected from it things that no group of geologists, good or bad, could deliver. A chief geologist must make management understand just what geology can do for their particular needs, what it will cost, how long it will take, and what risks are involved. If research work is involved, he must be prepared to present a good case to management lest they become impatient and cut off funds just before the successful completion of a project might be expected. He must not ask for, nor accept, funds he cannot reasonably use, nor should he accept, or ask for, projects his personnel is not competent to complete.

2) He must develop the confidence of management in his staff and his program.

3) He must provide management with clear, concise, and timely reports from his staff.

4) He must develop full confidence in his men, and from them, and back them to the limit with management. If he fails to develop such confidence, he should either remove those persons in whom he lacks confidence or refuse to accept responsibility for their supervision.

5) He must not allow management to make unreasonable, unethical, or improper requests of his personnel.

6) He must never *pass the buck* to his personnel when dealing with management.

7) He should make every effort to obtain for his men proper recognition and approval for sound geologic work.

8) He should see to it that his personnel are rewarded and promoted on the merits of their scientific and/or administrative work.

9) He should protect his geologic personnel from needless requests for paper work from the clerical or fiscal groups, yet he should also be keenly aware of the vast amount of *red tape* and *housekeeping chores* that a good clerical and fiscal group can handle and the time they can save professional workers. He should educate the clerical staff to the premise that they are hired primarily to assist the geologists and professional people and to help them accomplish the ultimate goal. He must also educate the professional people to the need for a certain amount of clerical work and recording of various activities, such as purchases, and the need for cooperation with the clerical units so that they may do their work efficiently.

10) He should make every effort to obtain proper working conditions for his men. This is difficult in many ways because geology necessarily calls for travel, inconveniences of the back country, and much time away from the family. Most geologists accept this, or they should not be in geology, but conditions should not be aggravated, and individuals should be allowed to plan their travel and off-duty times as far in advance as possible. Single men, if available, should be selected for the more isolated projects. In other words, give thought to the effect of orders on the person's family status. There are those who will say this is coddling, but actually it is just good business.

The supervisor should attempt to provide an adequate individual office for each geologist. Geologic office work is essentially creative thinking, and privacy and quiet will pay off in increased worthwhile production.

Both at the office and in the field the supervisor should see that his men are properly equipped to do the job required. Quite often companies pay large salaries and provide ample transportation expenses but balk at buying needed equipment.

Time and attendance are often a point of contention for geologists. Since most geologists work long and irregular hours in the field and are subject to the usual problems of scientific thinking in preparing reports, they resent clock-punching habits in the office. Supervisors will find that dogmatism about exact office hours usually results in less output. The important thing is to get results. Those who abuse this freedom of action are not desirable professional people and can be released, and those who are given it will produce more in the long run.

There has been a very disturbing trend among the younger geologists to try to adjust geologic work to the standard 40-hr week. This is due in part to the basic trends throughout industry and government and in part to management's insistence on adhering to time and attendance schedules. Few, if any, will rise to the top of the profession on a 40-hr week, and administrators who foster such thinking will not have a high-grade scientific group.

Obviously, the man who pays attention to all these requirements is going to be a full-time administrator at the sacrifice of his own scientific career. One method used to avoid this condition is rotation of high-level administrative jobs for a year or two among the geologists of the staff. This is a *have your cake and eat it* situation, which is too often unsatisfactory. Most organizations find this leads to administrative instability and is satisfactory neither to the administrator nor to the scientist. It usually lowers quality of work and quality and morale of personnel.

A geologist who has demonstrated that he is a good administrator should take pride in the fact that in making possible the achievements of many other geologists he has contributed far more to his science than he himself could accomplish as an individual.

Grinding Ball Rationing

Determining the optimum size assortment of grinding balls for a makeup charge is a practical means of improving mill operation.

by Walter L. Crow

MUCH has been published on highly technical phases of grinding. Very little has been written on how a mill man can improve his operations by determining the optimum size assortment of grinding balls that should be added as a makeup charge. This ball rationing is not to be confused with the ball ration used as an initial charge when the mill is started up.

Ball rationing is considered for one or more of the following purposes: 1) to increase throughput of the mill, 2) to reduce the power required per ton of ore ground to the desired size, 3) to reduce steel consumption per ton of ore ground, 4) to improve product size, and 5) to lower retention time of ore in the mill.

An increase in throughput of the ball mill offers a big advantage. Since total milling cost is the sum of fixed or indirect costs (capital investment, salaries, etc.) plus variable or direct costs divided by the tons of ore processed, and since indirect costs remain constant irrespective of increases in throughput, the total mill cost (in cents per ton) will decrease. This advantage can be realized in plants that can raise the rate of mining and all steps in ore processing to match the increase in throughput of the ball mill.

Indications That Rationed Charge Is Needed: When a one-size ball addition to a mill is being established, the following conditions may warrant ball rationing:

1) There may be a certain amount of tramp oversize that can be reduced by replacing a portion of the balls by a larger size.

2) There may be crowding of particles of reduced size but not of finished size, showing a deficiency of small-size balls.

When a new mill is started up, of course, a certain time is needed to get the processing running smoothly. During this period a further problem of ball rationing would be ill-timed.

Not all mills should attempt ball rationing, and these words of caution are offered. Most small mills, and some of the larger ones, have not the facilities to blend mine run ore for mill feed, and with a great variation in character of feed there may be a difficult problem in establishing even an optimum single-size ball charge. Small plants may find that this has taxed their personnel enough without going into ball rationing. This does not mean that the personnel lacks technical ability, but that facilities, personnel, and sufficient time are not available for careful testing. Moreover, the cost of such an effort may not be justified. Total savings in dollars and cents, through a relatively minor improvement in grinding practice, will not be as great in a small operation as in a larger one.

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Ball Wear Pattern: When one-size balls are used for addition, the seasoned charge in the mill ranges from balls of the original diameter to those small enough to purge from the mill. If a screen analysis of the charge is made using screens with openings of equal increments, such as ½ in., the weight of the balls on each screen will show a certain pattern, or distribution of the charge by weight, whether ball wear varies in direct proportion to its surface area as D^2 (attrition grinding), as maintained by Rittinger; or in direct proportion to its volume as D^3 (impact grinding), as maintained by Kick; or somewhere between these two figures as suggested by Bond (a combination of attrition and impact comminution).

These theories of ball wear do not hold true, in the writer's opinion, for apparently the rate of wear of different ball sizes in the charge is affected by size structure of the mill feed and by crystal size of the minerals. Also the physical and chemical characteristics of the ball may vary with the distance from its center.

There is evidence that there is a difference in the wear pattern of grinding balls of different manufacture. Some appear to be *self-rationing* compared with others.

The advantage of large balls in the charge is that they drop with greater impact and have a more effective *nipping* action on the larger particles. Small balls make a greater number of contacts because

there are more of them, so that attrition grinding is more effective and there is a higher crushing incidence due to nipping action on the smaller particles. Ball rationing is employed to change the size distribution of the ball charge to one that has a better ratio of impact, nipping, and attrition.

One-Size Ball Makeup for a New Mill: Before an attempt is made to work out a rationed makeup charge, the best one-size ball makeup charge should be established. Ball size is determined mainly by the factors listed below:

Ball

1) Specific gravity (affected by voids in the ball)
2) Shape
3) Homogeneity
4) Relative cost of balls by diameter

Mill

1) Inside diameter
2) Speed (peripheral speed, rather than percent critical speed)

Manner of Operation (Assuming One-Stage Grinding Only)

1) Open or closed circuit. (Percent circulating load of closed circuit)
2) Mill pulp density (specific gravity of pulp constituents)

Feed Material

1) Size structure of mill feed
2) Desired particle reduction
3) Character of ore
   a) Specific gravity of gangue and of mineral or minerals
   b) Grindability characteristics
      1) Comminution to crystal sizes
      2) Comminution through crystal sizes
      3) Sliming characteristics

Grindability tests have been made with laboratory-size equipment by mill manufacturers, institutions, and mining companies. These tests indicate grindability of the ore, but scale-size work has its limitations. The ratio between mill diameter, mill peripheral speed, ball diameter, and particle size which is obtained in laboratory work is not the ratio that exists in the full-scale operation. A mathematical solution of the problem may indicate the proper ball size. The simplest mathematical aid is the Coghill and DeVaney formula, $D^2 = Kd$, where D is the ball diameter, d the particle size, and K a constant varying between 25 and 50 depending on the relative hardness of the ore.

This empirical formula cannot always be trusted, and it is evident that many factors listed on page 752 under General Method of Rationing are ignored.

Bond has gone further in developing the empirical formula:

$$B = \sqrt{\frac{F\,W_i}{K\,C_s}\sqrt{\frac{S}{\sqrt{D}}}}$$

In this formula B is the diameter of the ball to be charged, in inches; C is the percent critical speed of mill; D is the inside mill diameter, in feet; F is the size of screen opening, in microns, that 80 pct of the new feed to the mill passes; K is a constant which has a value of 200 for a closed circuit ball mill; and S is the specific gravity of the ore. W_i is called the work index, which is determined in the Allis-Chalmers laboratory. This formula assumes the use of a spherical steel or iron ball and takes into account the more important factors listed above. The factor most difficult to determine is W_i. It is of course dependent on the sample of ore submitted for laboratory test and is limited by the shortcomings of laboratory tests. Some people question that the factor F is an ideal criterion.

When a new mining property is being developed it is often not accessible, so that sampling is not thorough enough to indicate all the types of ore that eventually will be encountered. It is important that the comminution problem of various ores be studied in terms of the subsequent metallurgical processes, both physical and chemical. The degree to which the ores will be blended before entering the ball mill should be taken into consideration. If no blending or poor blending is anticipated the most difficult grinding ore should be given the most weight in determination of ball size, although this size may be too large for the softer ore.

Through past experience some mill manufacturers have prepared tables that specify ball sizes for each mill size. Tables are usually set up with different ball sizes recommended under ore classified as hard, medium, and soft. The question is, how hard is a hard ore?

An important consideration is the ball size used by other mills with similar ores, especially when similar ball mills are used.

In an operating mill it is not difficult to determine whether the optimum one-size ball makeup charge is being used. Variation in grindability of ore is the chief complicating factor. It is better to add too large rather than too small a ball, although fewer balls are used, giving fewer contacts and less attrition grinding. This is a precaution against encountering ores that are more difficult to grind, which may cause an increase of tramp oversize to be circulated through the closed circuit, choking up the circuit and necessitating reduction of mill feed.

Too large a ball will reduce the larger feed particles with little tramp oversize, but the reduced particles will crowd before they reach the required size for further processing, and excessive slimes may also be produced. In closed circuit, recirculation of the crowded sizes will overload the classifier, requiring reduction in mill feed. Added to an open circuit mill, grinding balls that are too small allow tramp oversize to enter the next process, and balls that are too large do not produce the desired fineness of grind or liberation size, while at the same time they may produce too many slimes.

Prices of the different size balls are worth considering. The lowest-priced steel ball is commonly the 3-in. diam ball. Larger sizes are slightly higher in cost. For smaller sizes the price becomes rapidly higher. If 3½ and 3-in. diam balls give similar results the 3½-in. ball is preferable, as it gives insurance against production of excess tramp oversize in case the feed becomes more difficult to grind. However, the lower price of the 3-in. ball may be the deciding factor. Balls of 3-in. diam are more commonly used in beneficiation plants and are usually more available for immediate delivery.

It is an interesting contention that a grinding ball with a softer core is less subject to splitting from impact and that when the ball is worn down to the size considered of little value in comminution, it is then reduced in size at a faster rate by abrasion and thus ejected from the mill sooner, making way for the addition of balls of more useful size.

As in other experimental work in an operating circuit, it is good practice not to make too radical a change. If it is indicated that 4-in. diam grinding

balls would be more satisfactory than the 3-in. diam balls in use, it would be better to test 3½-in. diam balls first and then check results. Or, if it is thought that 2½-in. diam balls will improve results over the present use of 3-in. diam balls, it may be better to use only one quarter or one half the charge of 2½-in. diam balls to check for improvement before going to 100 pct 2½-in. balls as the makeup charge.

General Method of Rationing: How can the ideal ratio of different sizes of balls for a mill be determined? How can the ratio be varied? The second problem is relatively easy.

Many operating personnel in the cement industry believe that when raw materials and clinker are ground the seasoned charge contains too many balls worn to small sizes and irregular shapes, giving ineffective contact on impact. These take up space that could be utilized by larger spherical balls that would grind more effectively. To increase the ratio of larger balls in the charge the mills are periodically dumped, the charge is screened, and the larger balls are returned to the mill. *Cull* balls are replaced by new ones.

If it is determined that there is a shortage of small balls in the seasoned charge, the makeup charge may be partly replaced by one or more sizes of the smaller balls. This is a *rationed* charge.

Steps in Working Out the Ball Ration: Complete records should be kept so that the throughput of the mill, power consumption, and ball wear are known. It is also well to record liner wear, although this requires observation over a long period of time. It is very important to keep records of feed, discharge, classifier overflow, and classifier sands screen analyses. Classifier sands size structure will give indications as to whether smaller or larger balls in the charge will give better results. Davis's rules should be used:

1) Crowding will appear at the fine sizes of particles in the classifier sands, if the seasoned charge is graded too much towards the larger sizes of balls.

2) Crowding will appear at the coarse sizes in the classifier sands, if the ball charge is graded too much toward the smaller sizes.

3) Best efficiency is obtained when there is a minimum crowding at any size of the size structure of the classifier sands.

Complete records should be kept to show the effect of any change in ball addition to the mill throughput, power consumption per ton, and ball wear in pounds per ton. These changes will affect the size structure of the mill discharge and the classifier overflow and sands. Before the full effects of a change in ball addition occur, the ball wear pattern should be given time to reach its new equilibrium. This will require the time necessary for the old ball charge to be entirely replaced by the new charge. For example, if the ball load in the mill is to be maintained at 100,000 lb and 1000 lb of balls are added per day to maintain the ball level in the mill, it is reasonable to assume that more than three months will be needed to complete the modified ball charge.

If the new makeup charge is one that would increase the rate of comminution of the ball mill, and if the new ball charge reaches its equilibrium *without* an increase in feed rate, the new charge will *not* show an increase in throughput, the steel consumption will be too high owing to steel on steel wear, and power consumption per ton of ore ground will be unnecessarily high. To prove the value of a charge in ball ration, it is important that the mill feed be kept at capacity at all times.

A study of the classifier sands using the graphic method presented by Coghill maybe made. The size structure is plotted using the abscissa to represent each mesh size of the standard series screen and using the ordinate to represent the respective percent weight of material on each screen. If the plot shows a bulge in finer sizes, a smaller ball should be considered in the ration. The size and number of balls must be determined by trial and error. All the sizes of balls in the mill do work in reducing all the sizes of ore particles, but each size of particle is most effectively reduced by a certain size of ball. This is simply a restatement of Davis's rule. As Davis suggests, best results in grinding are obtained when the size analysis of the classifier sands is uniform.

W_i in Bond's formula and the K in Coghill and DeVaney's are subject to the weaknesses of laboratory determinations and may be somewhat in error in calculation of a one-size ball makeup charge. When an optimum one-size ball makeup charge, B and D, has been proved by practice, the formulas can be solved for W_i and K. By observing the bulges on a Coghill type of plot of the classifier sand size structure, it is possible to estimate a new F and D. With the variables solved for, W_i and K, and estimated, F and D, the formula can be solved for a new B and D, and these values can be used as an indication of the ball sizes to be added to the ration.

By screening a dumped ball charge as described under Ball Wear Pattern, it may be found that there is a deficiency in certain ball size or sizes in the wear pattern. This may be correlated with the bulges in the plotted curves of the screen analysis of mill feed and classifier sands and with the crystal sizes of the minerals being ground. This deficiency of a certain size of ball in the wear pattern may indicate that this size or one slightly larger should be added to the makeup charge for grinding improvement.

Ideally, comparative tests of different ball rations should be made in mills that are in parallel, with identical mill conditions, with feed as similar in character as possible, and with independent control of feed and water to each mill so that the mills may be fed at capacity. If the same mill must be used for comparative tests, any change in ore characteristics and liner condition must be correlated.

Conclusion

Attaining an ideal ball ration is not easy. However, by using common sense in applying established principles of grinding, by keeping complete records and avoiding changes that are too radical, and by allowing enough time for changes to take effect, many mill operators can increase the efficiency of their ball mills.

Acknowledgments

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References

[1] F. C. Bond: *Crushing and Grinding Calculations.* Allis-Chalmers Mfg. Co., Sept. 6, 1956.

[2] L. M. Barker and E. G. Lewis: Developments of Ball Mill Grinding Practices at New Cornelia. *AIME Trans.*, 1943, vol. 153, pp. 333-344.

[3] W. H. Coghill: Evaluating Grinding Efficiency by Graphical Methods. *Engineering and Mining Journal*, 1928, vol. 126, pp. 934-938.

[4] E. W. Davis: Fine Crushing in Ball Mills. *AIME Trans.*, 1919, vol. 61, pp. 250-294.

Production of Calcined Magnesite

At Gabbs, Nev., Basic Incorporated calcines natural magnesite from its open pit operations. The result is a closely controlled and uniform product having a specific reactivity for a particular use.

by Fred W. Menzl and Raymond E. Sutton

GABBS, Nev., in Nye County, is 140 miles southeast of Reno and about 31 miles north of the Southern Pacific railroad at Luning. The townsite lies at the eastern edge of Gabbs Valley, and plant and quarry operations are in the foothills of the Paradise Range at elevations from 5000 to 5900 ft. Hard-surfaced roads connect with main U. S. highways on the north and south.

Historical Background: Brucite, a magnesium hydroxide mineral, was discovered in the Gabbs area in 1927 and magnesite, the magnesium carbonate, was found later on claims originally staked and worked for the tungsten mineral scheelite. The brucite is on a granodiorite contact and the magnesite is usually some distance away from the granodiorite.

In 1941 Basic Magnesium Inc. was organized for the purpose of producing metallic magnesium for war use from the Gabbs magnesite ores. This operation necessitated development of open pit mines and construction of roads, housing, wells, power lines, and telephone lines. A plant was erected at Gabbs to produce magnesium oxide, and a complete magnesium reduction plant was constructed at Henderson, Nev. The Gabbs plant flowsheet[1] consisted of three-stage crushing, wet grinding in closed circuit with screw classifiers, flotation, filtration, and drying and calcination of the finely ground flotation concentrate in four Herreshoff furnaces to produce a magnesium oxide product with about 10 pct ignition loss. The plant operated until the end of 1944, when the emergency need for additional metallic magnesium ceased to exist.

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To quote Victor E. Kral: "In 1933 the United States Geological Survey estimated the tonnage of magnesite in the millions of tons, but, like the competing magnesite companies, could see no commercial value in such a desert deposit so far from a market. In about a decade it was supplying the world's largest magnesium metal plant."[10] According to Callaghan and Vitaliano,[9] 81,272 tons of magnesium metal were produced from 920,000 tons of ore from September 1942 until November 1944, when the plant was shut down.

By 1949 Basic Incorporated and its predecessor companies had shipped 225,000 tons of magnesite and 444,000 tons of brucite ore.[9] These were used principally in the Ohio refractories plant of Basic Incorporated.

In 1949 Basic Incorporated—at that time known as Basic Refractories Inc.—purchased the Basic Magnesium Inc. plant and mining claims at Gabbs and constructed a rotary kiln plant that was placed in operation December 1950. Although most of the magnesite and brucite mined in the area is used in the production of granular basic refractories by dead burning in rotary kilns, a substantial part of the magnesite is used in the production of calcined magnesite in Herreshoff furnace operations.

Uses of Magnesium Oxide: Brucite has a theoretical magnesium oxide content of 69 pct and magnesite 47.8 pct. Magnesium oxide, a chemical

widely used in industry, is produced chiefly from salt brines, and sea water, or by other chemical processes, but at Gabbs it is produced from magnesium carbonate ore. This is one of the very few operations of its kind in North America.

Magnesium oxide is used chiefly in the manufacture of oxychloride and oxysulfate cement, insulating materials, and rayon, and in the extraction of uranium from its ores. These account for the major part of U. S. oxide output. Magnesium oxide is also used in electrically fused magnesia, welding rod coatings, ceramics, glass, paper and paints and as a modifying agent in compounding synthetic rubbers, especially neoprene. By conversion to hydroxide it is used in the manufacture of milk of magnesia, magnesium carbonate, and other magnesium compounds.

Mining and Crushing: At Gabbs magnesite is selectively mined by open pit methods. Ore is removed in benches 10 ft high. Drilling is done with wagon drills, and loading with a 54-B 2½-yd Bucyrus Erie diesel shovel. The ore is hauled two miles downhill to the crushing plant in 15-ton Euclid trucks.

Mine run ore is reduced in three stages. First a 36-in. Superior McCully gyratory crusher discharges a 5-in. product to a 4-ft Symons standard cone crusher, which in turn produces a 1½ to 2-in. product. Conveyor belts and screens are incorporated in the crushing plant to control sizing. A movable belt stacker conveys the crushing plant product to mill stockpiles, each containing an ore of different grade, with a total storage capacity of more than 100,000 tons. A concrete tunnel 480 ft long is located under the stockpiles. Ore can be withdrawn through any one of 38 drawholes by a movable feeder mounted on rails over a 24-in. conveyor belt, which carries the ore to the tertiary crusher. This crusher, a 5½-ft Symons Short Head cone operating in an open circuit, is set to deliver a —½-in. product to feed storage bins ahead of the calcining furnaces.

View of Basic's rotary kiln looking toward the discharge of burner end. The kiln is 9½ ft diam and 398 ft long. It produces a high magnesia granular refractory material used in the lining of steel furnaces.

Plant Description: The magnesite ore is calcined in a Herreshoff furnace, 22 ft 3 in. OD by 48 ft 6 in. high, set on columns giving a total height of 60 ft. It is lined with super-duty fire brick backed up with magnesia insulation to a total thickness of 13½ in. The furnace is divided into 14 separate hearths, arched towards the center with a rise of 1 in. to the foot, and so constructed that the roof of one hearth forms the bottom of the hearth above. Clearance between hearths is about 3 ft. A circular opening, 5 ft 6 in. diam for the *in* hearths and 3 ft 10 in. diam for the *out* hearths, is left in the center of each hearth to accommodate the center drive shaft, to which the rabble arms equipped with plows are attached. The alternate *out* hearths also have openings along the periphery. The super-duty hearth bricks are of special shapes to make the arches self-supporting. Refractory life is excellent. There has been very little maintenance on the original installation. In operation the material on the first hearth is plowed toward the center of the furnace, where it falls to the next hearth below, on which it is moved outward toward the peripheral openings, and so on, moving in and out on alternate hearths until discharged from the bottom hearth.

The center shaft is made up of hollow cast iron sections, 33 in. OD, covered with 5½ in. of insulating material wherever it is exposed to high temperatures. It is supported by a step bearing on the bottom and is driven, through a bevel gear and pinion, by a 15-hp motor and speed reducer that gives it a counter-clockwise rotation of 1.2 rpm. A fan driven by a 15-hp motor circulates 7000 cfm of cooling air through the center shaft and rabble arms. The rabble arms and plows in the top seven hearths are made of cast iron, whereas the arms and plows in the lower seven hearths are made of Pyrocast, a heat-resisting alloy containing 20 to 30 pct chrome. Two 12,000-cfm fans, driven by 25-hp motors and mounted on the discharge side of multiclone dust collectors, furnish the induced draft for the furnace. A primary air fan furnishes air at ½ psi to the burners.

The furnace is fired through 20 individual burner boxes, located on the lower seven hearths, using Hauck No. 580 low pressure burners. The fuel used at present is a heavy bunker oil pre-heated to 250°F. A Viking gear pump circulates and supplies heated oil to the individual burners at 30 psi.

Originally the furnace was fired through burner tile inserted through the furnace wall, combustion taking place inside the furnace. This proved impractical because liberated gases from the carbonate ore prevented satisfactory combustion. The present burner boxes and combustion chambers are mounted outside the furnace shell, angled slightly so the flame does not strike directly on the center drive shaft. The box itself is lined with super-duty fire brick.

Calcining Operation: From the storage bins the ore is conveyed by belt and bucket elevators to the top hearth of the furnace. Feed rate to the furnace must be maintained at a steady flow to control the quality of the product. This is accomplished by use of a Hardinge constant weight feeder located under the feed storage silo. As the ore moves across the different hearths, and downward through the fur-

nace, it is heated at a carefully controlled rate. The desired degree of calcination is completed as the ore passes through the higher temperatures encountered in the lower hearths. Use of 20 individual burners introducing heat at different points on the lower seven hearths gives close control of the degree of calcination. Currently the time required for the material to travel through the furnace is 2½ hr. Again, this can be varied if necessary to attain the desired reactivity in the product. Dust from the multiclone collectors is returned to the No. 9 hearth. Exhaust gas temperatures are about 650°F. The temperature gradient through the furnace can also be adjusted over a considerable range.

Typical Temperatures in the Various Hearths
Temperatures °F

Top	1	630°
	3	990°
	5	1,080°
	7	1,200°
	9	1,380°
	11	1,380°
	13	1,440°
	14	1,170°

Cooling: Furnace discharge falls directly into a Stearns Roger cooler 5 ft in diam and 45 ft long. The cooler tube rotates at 5 rpm, the lower portion submerged in a tank of water. The feed end turns in a water-cooled bearing, but the discharge end is not cooled. Drive is through a 10-hp motorized speed reducer and chain-driven intermediate shaft with spur gear connection to the cooler.

The main shell of the cooler has water passage holes to allow circulation to three inside tubes. Entering at about 800°F, calcine passes through these inner tubes, assisted by internal flights, and is discharged at about 150°F. Travel time through the cooler is about 11 min.

Cooler discharge is conveyed to the top of two storage silos by screw conveyors and bucket elevators. Each of these silos is a duplicate of the 1200-ton furnace feed silo, but capacity is only 800 live tons owing to decrease in bulk density.

Instrumentation: Eight individual Brown potentiometers, located in a separate control room, are connected to thermocouples inserted through the walls of the furnace at different hearths. These indicate the gas temperatures. The slightest temperature change is immediately evident and visible to the operator. There is also a 12-point Brown strip recording potentiometer that gives a continuous temperature record of the most important hearths, discharge temperature of the shaft cooling air, and temperature of the furnace exhaust gases. Temperature and pressure gages are installed in the fuel lines. All important electrical drives are interlocked in proper sequence to prevent damage to the equipment or overheating of the furnace.

Product: Magnesium oxide as produced at Gabbs varies in size depending on the size of the furnace feed. A comparison of the furnace feed and product follows:

Size	Feed	Product
+ ½ in.	7.6	2.1
− ½ in. + 3 mesh	31.4	14.2
−3 mesh + 6 mesh	26.3	18.6
−6 mesh + 10 mesh	10.3	10.3
−10 mesh + 20 mesh	4.9	5.1
−20 mesh + 35 mesh	2.5	3.2
−35 mesh	17.0	46.5

Ignition loss of the finished product is carefully controlled, varying from 0.5 to 5.0 pct depending on the use for which it is intended. Since the raw carbonate ore contains about 50 pct carbon dioxide, production of 1 ton of calcined magnesite requires approximately 2 tons of raw ore, depending on dust loss and ignition loss of the finished product. Most of the impurities contained in the raw ore will still be in the finished product; therefore a calcined magnesite with a very low ignition loss will have an impurity analysis about twice that in the original ore.

The reactivity of magnesium oxide is the rate at which the oxide combines chemically with other substances. When magnesite is decomposed by calcining at low temperatures the resulting oxide is highly reactive. When the calcination is carried out over longer periods of time or at higher temperatures the oxide becomes less reactive. This decomposition begins at a temperature of about 662°F, but somewhat higher temperatures are required for complete removal of carbon dioxide within a reasonable time. The manner in which the heat is applied and the speed of calcination and cooling all affect activity of the calcine. These factors can be readily controlled in a multiple hearth furnace. Since each hearth is fired individually with one to three burners the time and temperature can be varied as required.

There are several methods for testing reactivity. An iodine method measures the rate at which the calcine absorbs iodine from a carbon tetrachloride solution. The Gillmore needle test uses the setting time of a mixture of magnesium chloride and calcined magnesite as an index of reactivity. As a production control test at Gabbs, the temperature rise resulting from the reaction of magnesium oxide with a magnesium sulfate solution under standard conditions is used.

Magnesite ore as fed to the furnace ranges from light to dark gray and weighs about 100 lb per cu ft. The calcined magnesite discharged from the cooler is grayish white and weighs about 65 lb per cu ft.

The calcined magnesite is sold by Basic Incorporated—under the trade name Magox—either as a pebble calcine in the size produced by the furnace or as a finely sized ground product. A typical analysis, on a loss-free basis, of Magox produced from the Gabbs ore is as follows:

SiO_2	2.31 pct
R_2O_3	2.37 pct
CaO	3.72 pct
MgO	91.60 pct

It is interesting to note that the same ores are used to produce both magnesium oxide and a high magnesia refractory clinker. Through the application of very high temperatures, 3200°F, and the addition of certain other materials a dark, hard, dense, practically unreactive crystalline clinker is produced in the rotary kiln, while temperatures of 1400°F differently applied in the Herreshoff furnace produce a highly reactive soft whitish powder.

References

[1] G. W. Nielsen: Growth and Development of Gabbs Concentrator and Oxide Plant. *Mining World*, December 1944, pp. 27-31.
[2] V. E. Kral: Mineral Resources of Nye County, Nevada. University of Nevada *Bull.*, vol. 45, no. 3, 1951.
[3] E. Callaghan and C. J. Vitaliano: Magnesite and Brucite Deposits at Gabbs, Nye County, Nevada. Open file USGS report, 1948.
[4] E. Callaghan: Brucite Deposit, Paradise Range, Nevada. A Preliminary Report. University of Nevada *Bull.*, 1933, vol. 27, no. 1.

by T. M. Berry

Circular Shafts for Deep Mines

FOR the past several years it has been growing practice to install circular shafts at deep mining operations. Several factors have brought this about.

Throughout eastern and midwestern coal fields circular shafts have been conventional for many years. Where large bodies of coal are mined, a production shaft may have a life of 20 to 30 years. Quantity production is essential; therefore the shaft must have a large cross-sectional area for larger skips and cages.

Mechanical mining has become a necessity if a company is to stay in business today. Continuous mining machines and cutting, loading, and hauling equipment must be taken in and out of the mines. If the access shaft is not large enough there will be expensive dismantling and assembling. This has become a problem at many operations, particularly in the western sections where ore was originally mucked by hand into small cars and hoisted by a skip through a narrow rectangular shaft having small compartments. Mechanical loaders must be dismantled to wheelbarrow size to go into these mines.

As underground workings are extended, greater volumes of air are needed for ventilation. This sometimes necessitates a shaft of large cross-section in order to maintain a low water gage or air pressure. Size of the shaft must be balanced with the volume and pressure required from an economical viewpoint.

These requirements for coal fields are true for other types of mines, especially when the material mined is found in a large body. This applies for salt, potash, some copper, some aluminum, and trona but does not necessarily apply where the material mined is found in pockets, faulty conditions, steep slopes, or vertical seams.

For a shaft area of 120 ft or more, a circular shaft has often been found more economical than a rectangular one, particularly if concrete lining is required. If the net area is to be 120 sq ft, it may be necessary to sink a circular shaft larger than this area, but it need not follow that a rectangular shaft having the neat required area is cheaper to construct. And although a rectangular shaft generally offers more usable space, it will be found that most of the space in a circular shaft can be utilized to good advantage. Large compartments are required for skips, cages, and access ways. Remaining segments are used for pipes, power cables, and counterweights.

In some parts of the country shafts are sunk through rock that is self-supporting and will not slake, slab, or spall when exposed to air, water, or varying climate. In such cases it may be more economical to construct a rectangular shaft, but even where there is good rock that needs no lining a circular shaft is sometimes worth considering, since the arch of a curved section offers the strongest support against pressure from the outside. If a relatively large shaft is to be sunk through good rock, it may be better to seek the natural support of an arch from the rock, particularly if long range maintenance could create a problem or if there is a chance of *heavier* ground or of ground movement.

Advantages of Symmetrical Working Area: It is easier to sink a round shaft than a rectangular, be-

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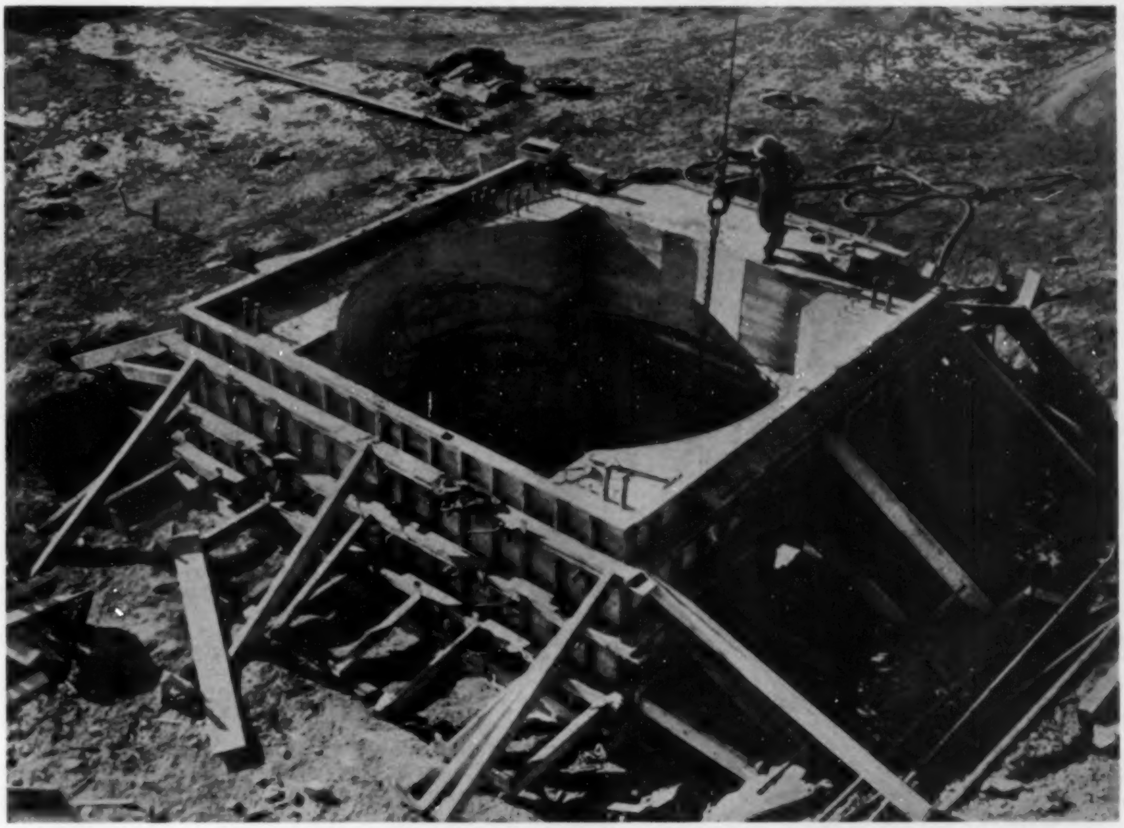


Square collar of a circular ventilating shaft in early stages of the work. Collar extended 30 ft below ground level to anchor shaft firmly in place before first of circular lining was placed.

cause all points on the periphery are on the same radius about the axis of the shaft—the working area is compact and symmetrical. This factor was not so important when hand drilling and hand mucking were common, but mechanization in shaft sinking has developed along with mechanized mining. Much of the labor-saving machinery lends itself better to round shafts than to rectangular ones. Of course there are exceptions. One in particular is the bridge crane mucking device that operates better in a rectangular shaft, but even this can be adapted to a round shaft.

A drill jumbo has been developed to replace the hand-held jack-hammer, cutting shaft drilling time in half. Drills are mounted on jibs radiating from the center of the machine. On a four-drill jumbo drills operate through a 90° arc and on a two-drill jumbo through 180°. For this reason the drill jumbo is much more efficient in a circular shaft, although it can be used in a rectangular opening that is wide enough.

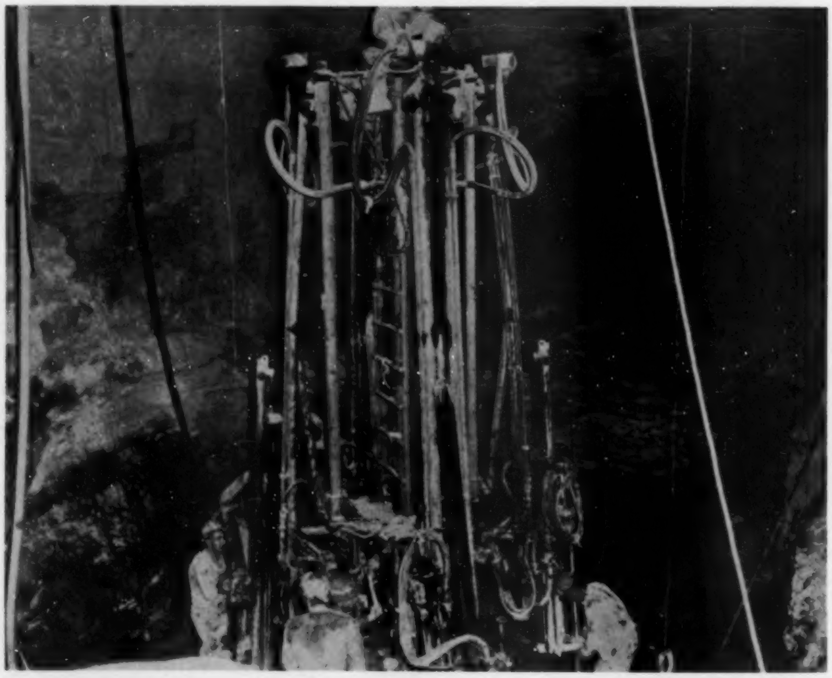
Methods of loading loose rock in shafts have improved during the past few years. Here again shaft size and shape are important. One of the first mechanical means of mucking in a shaft was a clamshell to load into sinking buckets. There are several methods of operating the clamshell in a shaft. An early method still in use employed the principle of the bridge crane. Supports for the bridge are located in the shaft lining, attached to the timber or steel sets, or anchored in the rock if the shaft is unlined. The bridge is designed so that it can travel backward and forward in a rectangular shaft or rotate in a horizontal plane in a round shaft. A two-drum hoist controlling raising or lowering and opening or closing of the clamshell is mounted on the bridge, which is lowered into the shaft as sinking proceeds. The clamshell loads into a shaft bucket that is hoisted to the surface for dumping.

Another loading method utilizes a clamshell mounting an air tugger that spools the closing line. The holding line by which the clamshell is raised or lowered is attached to the hoist of a crane at the shaft collar. The men at the bottom of the shaft signal the hoist operator when the bucket is to be raised or lowered. Bucket swing is controlled by two men with tag lines that allow the clamshell to be pulled to any position in the shaft for loading or over the shaft bucket for unloading. One man operates the air tugger to open and close the clamshell by means of two lines to the operating air valve.

In a similar method both the closing line and the load line of the clamshell are attached to hoists at the shaft collar. A man at the bottom of the shaft operates the two hoists, which are controlled by solenoid valves.

A method similar to the bridge crane uses a two-drum hoist to operate the clamshell, which loads into a skip. The skip is raised a short distance up the shaft to a dumping station where a shaft muck bucket is stationed. The skip dumps into the muck bucket, which is then taken to the collar.

Another method recently developed consists of an air or hydraulically controlled clamshell on an air or hydraulically operated boom is mounted beneath the operator's cage or platform. The entire device is



Cleveland LeRoi jumbo drill in operation on circular shaft. Machine has four rock drills with a 6-ft feed, mounted on booms controlled by compressed air motors. Conventional mine hoist with 350-hp motor and line speed of 900 fpm was used to hoist drill in and out of shaft.

usually supported in the shaft in one of the compartments of the steel or timber sets.

Eimco Corp. has mounted on crawler tracks the equivalent of one of its Model 21 overshot loaders, which ordinarily operate on rails. This machine maneuvers in confined space and readily loads into shaft buckets. The loader is new and has been used on two jobs so far—a large rectangular shaft in West Virginia and a concrete-lined shaft of 18-ft diam sunk by the Dravo Corp. in Wyoming. On the basis of this limited experience, the machine seems to offer many advantages in shaft mucking. It loads faster than a clamshell and is safer to operate.

Use of any of these machines—drill jumbos or muckers—depends on the size and shape of the shaft. Most of them operate better in a round shaft than in a narrow rectangle. If the required area of a shaft is so small that mechanical methods cannot be used in sinking, it may prove cheaper to construct a shaft in which drill jumbos and muckers can be used.

Resistance to Ground Forces: Many shafts penetrate through layers of sandstone, siltstone, schists, and other rocks requiring a concrete lining to prevent caving, spalling, or squeezing. Where only a thin protective lining is needed to prevent air slaking of rock, there probably is little difference between lining a round or a rectangular shaft. However, if the ground will not support itself or if water acting on the material may cause it to cave or slip, then a concrete-lined circular shaft will best resist these forces. It goes without saying that it is simpler and cheaper to design and use concrete against compressive stresses than against flexure. Bending in a straight wall requires reinforcement; compression in a circular shaft lining does not. This does not mean that reinforcing steel is omitted altogether in circular shafts. Failure due to shear can occur in a circular shaft as well as in a rectangular one, but less steel and concrete should be necessary. In bad ground reinforcing steel is used in either type of shaft. Unbalanced and indeterminate forces can be exerted against the shaft lining, and it is wise to provide a measure of safety.

Advantages of Circular Lining Forms: Because the arch offers stronger support, forms for concrete lining in a circular shaft can be of much lighter construction than the materials necessary to take bending in a straight wall form. A round form handles better in the shaft and can be shifted in less time. If forms are removed from the shaft after each concrete pour, a round form can be stripped and removed in four pieces, whereas a rectangular form usually must be made up of six pieces if it is to be set or stripped easily. If the forms remain in the shaft after a concrete pour is completed and the shaft is excavated deep enough for the next pour, then the forms are collapsed and slipped down to position for the next pour. A round form collapses and slips more readily than a rectangular one; in fact, a collapsible rectangular form would be of complicated design and not nearly so feasible.

Ground water is a problem in most shafts, both during sinking and after the shaft is completed. The best way to cut off water flow is to pregrout before the rock is excavated. This is done sometimes in relatively shallow shafts by drilling long holes of the required depth and pressure grouting before the sinking is started.

In most cases grouting is done as sinking progresses. Test holes are carried ahead of sinking to intercept water before the rock is blasted loose. If a test hole indicates water, grout holes are drilled and grout is forced in to shut it off. This operation is the same for circular or rectangular shafts, but for any given water condition, higher pressure can be applied in a circular shaft.

When water is not stopped by pregrouting it must be panned so the concrete lining can be placed, but it will still find its way through the lining, particularly at the cold joints where the concrete does not bond. If the inflow is so great the shaft cannot be operated, grout must be forced behind the lining in an attempt to stop the flow. Grouting behind the

This ¾-cu yd clamshell bucket, attached to a surface hoist, provides another mucking method. Air tugger mounted on the bucket spools the bucket's opening and closing lines. Third man from left operates clamshell and man at right signals hoist operator when to lift 2½-cu yd muck bucket.

completed lining is always a tedious process because there is no way of knowing how much force this is applying on the concrete lining, or how the grout travels once it enters. Extreme care must be taken to avoid fracturing the completed lining in the area being grouted.

Because it is naturally resistant to outside force, a round shaft is best when grouting behind the lining is necessary. If the shaft is for ventilation only, no buntons are needed, but when struts or buntons are to be used, grouting can be done in a round shaft before they are installed. This is the most satisfactory method, as some grout will leak through the lining and coat the installed members, which must then be cleaned and painted. If the lining of a rectangular shaft is to be grouted, it is almost essential to have all buntons and struts installed to strengthen the straight walls against grouting pressures. It is very easy to crack the lining if it is a straight wall.

When the lining of a round shaft is being grouted, increases in pressure give some indication of the force being applied; pressure limits must be set according to experience, judgment, thickness of lining, and type of surrounding rock. During grouting, after a period of time, pressure gradually builds up to the desired limit. It may build up quickly if the voids are small.

In any case, in a round shaft the pressure will continue to build up and, if allowed to go too high, will abruptly break out the lining. In a rectangular shaft the grout may be filling a void behind the straight wall with a gradual increase of pressure. In this case the pressure will become constant. There is no way of knowing whether the grout is finding new channels to spread behind the lining or whether the wall is gradually bending and failing. In fact, before failure is noticeable the pressure may be decreasing.

Sinking the Shaft: There are several ways to sink a shaft. One method commonly used in sinking a round concrete-lined shaft is to complete the excavation and lining before installing any buntons or struts. Guides and a crosshead are not necessary unless required by state law. Experience has shown that this is a safe and economical procedure. The entire shaft area is open, with no obstructions to getting equipment and materials in and out. This permits the use of larger mechanical equipment for drilling and mucking. It permits removal of concrete forms for cleaning and repair. Unit concrete pours can be of greater length, limited only by stability of ground instead of the weight of a segment of the left-in-place form. Runs of 100 ft of lining have been completed successfully in good ground.

In many cases buntons and guides are installed as sinking and concreting progress. This requires using a crosshead, since there is not enough clearance to get men, materials, and equipment in and out of the shaft. Restricted working space and hoisting clearances create a hardship in the proper and safe execution of a job.

It would prove little to compare the cost of a finished round concrete-lined shaft having skips or cages and manways with the cost of a finished standard rectangular timbered shaft. In general, initial cost of a round concrete-lined shaft will be greater, but maintenance must also be considered, together with a survey of all possible uses to which the shaft may be put—production, transfer of men and materials, ventilation, or a means of getting larger equipment into the mine.

When the time comes for a new installation, the types and sizes of shafts that may fit a given set of requirements should be compared. A shaft sinking contractor should then be asked for a cost estimate of two different types or an alternate type if he thinks this will fit the circumstances with a reduction in cost. Too many shafts are designed and constructed according to convention. Be ready to change procedure if it reduces cost without sacrificing quality or usefulness.

Geology of the San Manuel Mine

by J. D. Pelletier

SAN MANUEL orebody is a disseminated copper deposit in quartz monzonite, monzonite porphyry, and diabase.

Quartz monzonite, which is Pre-Cambrian[1] in age, is exposed in an area including No. 1 and No. 4 shafts and extending about 2400 ft southeast from No. 1 shaft. It is also exposed in the bottom of No. 2 shaft and in a zone roughly 500 to 1200 ft southeast of No. 2 shaft having its long dimension along a northeast-southwest axis. Churn drilling has shown all these exposures to be parts of a contiguous mass of quartz monzonite lying within and beneath the ore zone.

Late Cretaceous[2] monzonite porphyry comprises the bulk of the remaining rock encountered below the conglomerate. In general, the porphyry occurs in two large masses that are separated by a projection of quartz monzonite south of No. 2 shaft. The porphyry masses converge to the east. The north area of porphyry is a sheetlike[3] mass lying above quartz monzonite. The south area has not been bottomed by any drilling south of the orebody and may be a stock.[3] Monzonite porphyry also occurs in the form of dikes cutting quartz monzonite. These dikes become more numerous with proximity to the larger masses of porphyry and generally trend northeast-southwest.

Several diabase dikes, intrusive into quartz monzonite and monzonite porphyry, have been exposed in the mine openings. Mineralization of all diabase dikes is similar to that of the rocks they intrude.

Andesite porphyry dikes have been noted in a few instances. Some of these dikes are unmineralized, while others are lightly mineralized with pyrite. The mineralization and hydrothermal alteration in all cases are of a different character than that of the intruded rock. Andesite porphyry is probably, as Schwartz suggests,[4] the intrusive equivalent of the lava flows of the Cloudburst formation, the mineralization being of a later age than the ore mineralization.

The Cloudburst formation was cut by No. 3A and No. 3B shafts and by drifting on the westernmost part of the 1475 level. This formation contains two members. The upper member is a conglomerate made up mainly of quartz monzonite fragments but containing some fragments of all the older rocks in the area. The matrix tends to be arkosic, but granitic sand and gravel are not uncommon. The conglomerate is poorly cemented but relatively well sorted as compared with the overlying Gila(?) conglomerate, having beds of sand and gravel alternating with beds of larger boulders. Slickensides are frequently seen on bedding planes. Tuff beds are found in the conglomerate and in the underlying member, which is composed of interbedded flows, flow breccias, and conglomerate. Where not distorted by drag adjacent to the San Manuel fault, the average strike of the conglomerate is N 5° W and the average dip is 30° to the east.

The contact of the Cloudburst formation with the overlying Gila(?) conglomerate in No. 3A shaft was an unconformity. In No. 3B shaft the contact was marked by an irregular tuff bed but here, and in the exposures of this contact on the 1475 level, the bedding of the two formations is parallel—or very nearly parallel—and in the 1475 level exposures, it was not possible to pinpoint the exact contact because of the similarity of the two formations.

A small tuff bed near the bottom of 3A shaft was mineralized with pyrite and a trace of chalcopyrite. This mineralization is later in age than the ore mineralization, since the Cloudburst formation is not mineralized where it is seen in depositional contact with mineralized porphyry on the surface.

Rhyolite dikes were intersected in several places on all the levels of the mine. Rhyolite is not mineralized by hypogene copper minerals but is occasionally stained by migratory chrysocholla where the dike is in, or close to, the zone of oxidation. Chlorite was noted coating joint faces of several rhyolite dikes. Rhyolite dikes are known from surface exposures to intrude the Cloudburst formation but do not intrude Gila(?) conglomerate.

Gila(?) conglomerate was cut in the upper parts of shafts 2, 3A, and 3B, and on the 1475 level southwest of No. 2 shaft. Fragments composing the upper portion are derived mainly from basic flow rocks, while the lower beds are derived from granitic rocks. The Gila(?) conglomerate contains no hypogene mineralization or alteration. The average strike is N 50° W and the average dip is 35° to the northeast.

Structure: The oldest of the important post-mineral faults is the San Manuel fault. In its underground exposures, this fault has an average strike of N 66° W and an average dip of 26° to the southwest.

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Outcrop of North orebody in right foreground between San Manuel fault and West fault. Subsiding conglomerate over South orebody in center background left of headframe.

Typically, there are 1 to 3 ft of red gouge and slickensides on the fault surface. On the footwall side, immediately beneath the red slickensides, there are 5 to 15 ft of gray gouge with irregular slick faces aligned more or less parallel to the fault and sometimes containing harder fragments with slightly rounded edges. Beneath the gouge, the underlying rock is badly fractured and grades into less fractured, normal rock 50 to 100 ft below the fault surface.

The conglomerate found in the hanging wall in exposures east of the Hangover fault is not badly disturbed but contains a few small slips close to the fault surface. West of the Hangover fault, besides showing small slips adjacent to the San Manuel fault, the Gila(?) and Cloudburst conglomerates show considerable drag for a distance of 300 ft above the plane of the San Manuel fault.

There are a number of faults which strike N 20° W to N 25° W and dip steeply to the east. These exhibit varying amounts of normal fault movement and are younger in age than the San Manuel fault. The most important of these are known as the East fault, the West fault, and the Hangover fault, the latter being in reality a zone of faulting.

A large reverse fault lying between the north and south limbs of ore was intersected by drifting on the 1475 and 1415 levels. This fault, known as the Vent Raise fault, strikes N 59° E and has a dip that varies from vertical to about 70° to the southeast. On the 1475 level, the Vent Raise fault cut the East fault or a branch of the East fault and is therefore considered to be younger than the northwesterly striking, easterly dipping system of faults.

Mineralization and Hydrothermal Alteration: The ore lies within a mineralized zone having a width of 8000 to 9000 ft and a known length in excess of 9300 ft. To define ore, an arbitrary assay cutoff of 0.50 pct copper is used.

The upper and western portions of the orebody are separated into two branches by an area of lean, weakly altered hanging wall rock. These two branches converge at depth so that, in cross section, they may be likened to a *U* or *V* leaning to the northwest. The northwesterly limb of ore is referred to as the North orebody and the southeasterly limb as the South orebody.

The North orebody has a strike of about N 60° E and dips about 50° to the southeast. The western portion of the South orebody has a strike very nearly parallel with that of the North orebody, or N 60° E, which gradually swings about to the east where the strike is approximately N 45° E. The dip of the South orebody is variable, the upper portions dipping southeast and the lower portions arching under to the northwest and joining the North orebody. To the east, the central area of lean material gradually diminishes to a core and then disappears as the two limbs join to form a single mass of ore.

The main primary minerals are chalcopyrite, pyrite, and quartz, with minor amounts of molybdenite. These minerals are distributed quantitatively into three zones known as the ore zone; the hanging wall zone, which lies between the North and South orebodies; and the footwall zone, which surrounds the ore and hanging wall zones.

The ore zone, averaging 0.80 pct Cu, contains most of the chalcopyrite, quartz veinlets, and molybdenite. Pyrite is present in about equal proportions to chalcopyrite. The yellow sulfides are finely disseminated through the rock but also appear as veinlets or, more often, scattered on fractures. Molybdenite usually forms a slick coating on fractures or accompanies quartz veinlets and is present in sufficient quantity to be recovered metallurgically. A "sericite-pyrite-chalcopyrite"[8] type of alteration in the ore zone is recognized in underground exposures by the moderate gray color of the rock, the presence of altered but easily recognizable biotite, and the presence of pyrite and chalcopyrite in moderate quantities.

The hanging wall zone is simply a lean version of the ore zone with lesser amounts of all the primary minerals. This zone is gradational with the ore zone and the amount of mineralization depends on the distance from the ore zone. Alteration here is classed as the "marginal biotite"[8] type and is recognized by the dark gray appearance of the rock, fresh looking biotite, and weak pyrite-chalcopyrite mineralization.

The footwall zone is radically different from the ore zone except for the area where it grades into ore. Pyrite is the chief mineral here and occurs in much greater quantities than in the ore zone. The strongest pyrite is found south of the ore zone where it composes 10 to 20 pct of the rock by weight. North of the ore zone the pyrite content is somewhat less and gradually diminishes to a very small amount about 1500 ft north of the ore zone. Chalcopyrite is seldom seen in the footwall zone, and then usually as a tarnish on pyrite. Quartz veinlets are very rare and molybdenite does not occur in visible quantities. In the footwall zone alteration is of the "hydromica-

pyrite"[5] type, characterized by the light gray appearance of the rock, absence of recognizable biotite, and abundance of pyrite.

A distinctive chlorite[6] alteration occupies an irregular zone within the South orebody, having its long dimension in a northeast-southwest direction, parallel to the long dimension of the South orebody. The chlorite is found chiefly as a coating on fracture surfaces which is locally very strong, in a few places permeating the rock.

It was originally thought that a close relationship existed between chlorite alteration and the better grade of copper mineralization. A comparison of this zone of chlorite alteration with the better than average grade of ore shows many broad similarities, though not always in detail. Owing to the fact that chlorite also alters post-mineral rhyolite, it is believed that any similarities that exist are due to a mutual structural control rather than a mutual source of mineralization.

Ore occurs similarly in quartz monzonite, monzonite porphyry, and diabase, in a zone roughly coincident with the contact of the large sheetlike mass of monzonite porphyry with the intruded quartz monzonite. This relationship does not hold true at the eastern end of the orebody, but here the ore is diminishing in cross section. It is difficult to relate the ore directly with the intrusion of porphyry, since it shows no preference for either rock and does not occur similarly where the large mass of porphyry to the south intrudes quartz monzonite. A possible theory is that the similarity in shape of the sheetlike mass of porphyry and the ore zone, as well as the later chlorite alteration, is due to a mutual, though unknown, structural control.

Oxidation and Secondary Enrichment: The upper portions of the orebody, with the exception of the western end, and much of the central lean hanging wall zone have been oxidized or partially oxidized.

The chief minerals resulting from oxidation and enrichment are chrysocolla, chalcocite, and various iron oxides. Cuprite, native copper, and black copper oxides are often seen where the oxidized zone grades into the chalcocite zone. Copper carbonates are very rare, only one small specimen of malachite having been recognized in all the drifting.

As mine openings and diamond drilling make more data available, considerable thought has been directed toward separating and classifying stages and types of oxidation, so that the overall oxidation pattern may be more clearly understood. It is possible to separate oxidized rock into two general types, depending on the color iron oxides impart to the rock.

The first type, identified by a deep red or reddish-brown color, is seen at the surface, in the upper parts of shafts 1 and 4 and in diamond drillholes extending above the top of the sulfide ore at the east end of the South orebody.

Comprising much of the oxidized ore zone—the chief ore mineral is chrysocolla—this type of oxidation is characterized by complete or nearly complete oxidation of the copper minerals and a relatively sharp line of demarcation between the oxide ore and the underlying sulfide. The absence of leaching and migration of copper from the oxidized zone to form an appreciable enriched chalcocite zone is quite marked in the San Manuel orebody. Thus the chalcocite zone, with variable amounts of oxidation and local enrichment, is not important tonnage-wise, so that—metallurgically speaking—the ore can be mined as clean sulfide with a minimum of mixed sulfide-oxide ore.

Oxidation of this type occurred in at least three stages: 1) during the erosional cycle preceding deposition of the Cloudburst formation; 2) during the erosional cycle preceding deposition of the Gila(?) conglomerate; and 3) during the present erosional cycle. Much of the oxidized ore explored by churn drilling in the central and eastern portions of the mine is probably of the *red* type of oxidation.

The second type of oxidation is characterized by a yellow to tan color of rock probably due to a lack of hematite and to the presence of limonite and goethite.[7, 8] It is typical of all the oxidized ground encountered in the deeper mine openings. Oxidation of the sulfides is not always complete and many rather large areas of primary sulfide rock or partially oxidized rock are surrounded or nearly surrounded by *yellow* oxidation. The outer margins of this oxidation generally contain chalcocite as well as primary sulfides and much iron oxide stain, but very few oxide copper minerals. Enrichment is very slight, if any. The copper content is usually not increased to any marked degree and occasionally is less than that of the primary ore. Chalcocite, and sometimes native copper and cuprite, occur along the top and sides of deep tongues of this yellow oxidation in about the same quantities in which they are found beneath them, so that there is often an inversion of the normal sequence of oxidation—the primary ore lying above secondary ore, which in turn overlies oxidized ore.

Deep tongues of yellow oxidation are known to follow rhyolite dikes, the San Manuel fault, and other northwesterly-trending post-mineral faults. In some cases no structural control is evident, but it may be surmised that the path of oxidation was controlled by local differences in permeability of rock.

This type of oxidation invades the sulfide ore locally along certain faults and in some fringe areas but has not been found to be of particular economic importance. The intensity of oxidation of ore minerals and the volume of such material relative to the volume of sulfide ore is so limited that it does not affect stope layout or draw. The distinctive coloration and mineralogical characteristics do, in some instances, provide a marker and guide for the stope engineers when they are evaluating their draw data.

Yellow oxidation extended much deeper between the two limbs of ore than in the ore itself and extended deeper than previous oxidations, so that in cross section the oxidized zone has the shape of a trough with its sides impinging on the two limbs of ore.

Acknowledgment

Acknowledgment is due the officers of San Manuel Copper Corp. for permission to use the information presented.

References

1 N. P. Peterson: Geology and Ore Deposits of the Mammoth Mining Camp Area, Pinal County, Arizona. Arizona Bureau of Mines, Geological Series No. 11, Bull. 144.

2 S. C. Creasey: Personal communication.

3 G. M. Schwartz: Geology of the San Manuel Copper Deposit, Arizona. *USGS Prof. Paper 256*, 1953, p. 9.

4 Ref. 3, p. 12.

5 Ref. 3, pp. 19-32.

6 G. M. Schwartz says of a specimen of this material collected on the 1285 level: "The index of refraction 1.59+ and very low birefringence indicate chlorite, but the X-ray pattern is very nearly that of antigorite. (Winchell considers antigorite a member of the chlorite group but most investigators include it in the serpentine group.) I think for the present that we may call it chlorite."

7 G. M. Schwartz: Ref. 3, pp. 37, 57.

8 G. M. Schwartz: Oxidation and Enrichment in the San Manuel Copper Deposit, Arizona. *Economic Geology*, 1949, vol. 44, No. 4, pp. 273, 274.

Cutting Costs with Aerial Photography

by Lewis H. Reiland

Delivering fast, low-cost reconnaissance to the engineer, this modern method follows up with reliable maps at a fraction of ground survey costs.

IN 1920, for the first time, the U. S. Geological Survey employed aerial photography in constructing planimetric maps. Contours were added by aerial photography and cultural details corrected. From 1925 to 1929 photogrammetric plotting machines and instruments of foreign design appeared in America for use in constructing complete topographic maps. During this period the only American technique developed was the Brock process, carried out with great success by Aero Service Corp. of Philadelphia, a pioneer in the field of photogrammetry. Between the first and second world wars the Multiplex projector, the Aerocartigraph, and the Stereoplanigraph appeared. The Multiplex projector, most popular of the three, determines three-dimensional values with very high accuracy. Many refinements have been added year by year, and it is now possible to photograph vast areas in a very short time and produce planimetric, topographic, and geologic maps of great value at very low cost per acre as compared with all methods previously known and in use. Both on the ground and in the air, however, accurate results can be produced only with highly skilled personnel and costly scientific instruments and machines.

As early as 1928 the writer collected from the U. S. Army Engineers all available formulas and data on photogrammetry and personally contracted a local project of 2800 acres to be surveyed from the air. From the 10,000-ft altitude required for scale the cameras, each equipped with 4-K filters, pierced a ground haze of about 5000 ft, achieving clear, definable photography. The result was so gratifying, and the continuing progress in this method of surveying and mapping so great, that in the matter of economy it can hardly be surpassed. Pocahontas Land Corp., for example, constantly refers to its complete file of aero prints, covering its entire ownership in West Virginia, Virginia, and Kentucky. Photostats are enlarged or reduced from these prints to match the scale of company maps, to which various features are then added.

In view of the ever increasing cost of mining, surveys, labor, machinery, supplies, housing, and taxes, coal mining men constantly seek the most economic methods of development. If the lowest possible cost per ton of coal produced is to be realized, there must first be an appraisal of potential resources on the property, above and below ground. Accurate maps are needed and geologic information at lowest cost. Suppose then, that photogrammetry is used as a means of mapping the property, estimating its worth, and projecting plans for development. The procedure is as follows:

The boundary of the property is laid out on a small-scale USGS 15-min quadrangle topographic map. Assume, for example, a scale of 1:62500 or about 1 mile to the inch, showing contour intervals of 50 ft. If a general planimetric map is available

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TOP: Wild A-7, a $55,000 stereoplotting instrument, used in compilation of aerial topographic maps. BOTTOM: Wild A-8, precise stereoplotting instruments used in compilation of topographic maps from air photos by photogrammetric methods.

this can be used to supplement the survey map, that is, to show triangulation control, property lines and corners, known bench marks, and other horizontal and vertical control. Locations of boreholes and gas wells, along with other pertinent data, are also given the photogrammetric engineers, who study the outline closely to establish the location and the number of flight lines and ground signals necessary for vertical and horizontal control. Ground signals are laid so that each pair of photos to be selected for stereoscopic viewing will have approximately nine vertical and several horizontal signal points in view of the camera, within the pair selected. When all such arrangements are perfected, the planes go aloft for photographing. Flying the average coverage of 5000 to 10,000 acres requires only a few hours, and the negatives of the resulting photography are in the laboratory for processing shortly thereafter. These negatives are developed immediately. In original form each contact print is 9x9 in., usually at a scale of 1 in. to 1667 ft—or larger, as the job requires. The 1667's cover about 9 square miles overall. Much of this is deleted along all four sides because of the distortion caused by the lens.

Photoreconnaissance at a few cents per acre and topographic maps at half the cost of ground surveys —these are the air-survey economies that put up-to-date mapping coverage within the budget of deep and strip mining. These savings, however, are only part of the reason more deep mining and stripping engineers are planning aerial mapping of their property. The multiple uses for aerial maps and photos are the big advantages.

Unlike ground surveying, aerial mapping is flexible. The same set of aerial photographs will do three jobs. They are used for stereoscopic study. They can be assembled into a photomosaic, a good reconnaissance map. Then, when the areas of interest are defined, a contour map can be compiled from this same aerial photographic base. Each of these products of the aerial survey can be used in money-saving ways.

First of all, the aerial mapper delivers individual aerial photographs to the mining engineer. These are taken with an overlap of 50 to 60 pct, so that pairs of photos may be studied stereoscopically. Seen in this third-dimensional view the relief is great, and details may be observed that often go unnoticed on the ground. For example, the geology of an area can be studied. Such geologic features as benching and outcropping may be traced, whereas in observation on the ground they are often obscured by brush. This stereo-viewing will never take the place of first-hand observation and study of surface geology, but it is an important supplement, directing ground studies to areas of primary interest. During the weeks when weather makes ground studies virtually impossible, stereo pairs of aerial photographs are useful in scanning the area and making plans for later field work.

Timber for mine use is always a problem with the engineer, and here the aerial pictures can help in evaluating timber resources. Usually a sampling scheme is used on timber evaluation. Several predetermined lines through a stand of timer are evaluated by a fast field cruise. The size and type of timber is annotated on the photograph. Then an office evaluation may be made of the entire area by stereo study of the photographs.

Although not quite as accurate as the topographic map, the photomap records a wealth of cultural detail in true relative scale. It can be the base for planning reforestration or reclamation of mined-out areas. In those states requiring that a bond be posted and a map submitted before an area is worked, the photomosaic satisfies the map requirements at minimum cost.

With the photomap at hand, the areas of interest can be defined for detailed topographic mapping. The topographic map is the most exact product of aerial mapping. It is compiled in one half to one fifth the time needed for ground surveys. Its costs are very much less than with plane-table methods, and its accuracy equals or exceeds that of maps prepared by ground methods.

With an aerial topographic map the mining engineer can, among other things:

1) Estimate coal and timber acreages, quantities, and volumes.

2) Delineate outcrop lines.

3) Plot boreholes.

4) Locate spoil dumps.

5) Lay out plants, housing, access roads, and service and communication lines.

6) Plan rail spurs, supply and delivery tracks, and other large plant facilities.

7) Compute overburden.

8) Plot workings for tax purposes.

9) Plot interior and property boundary lines and triangulation.

10) Estimate cost of general construction to a high degree of accuracy.

Usefulness of the map develops within the mining company. A number of companies have found that after the maps are at hand scarcely a week passes in which an office solution is not found for problems previously solved only by sending men into the field.

Cost of an air survey varies according to size and shape of the area, scale of the maps, amount of existing control, and the contour interval. But for areas of 1000 acres or larger, the air method always costs much less than ground surveys. Aerial mapping of a 7210-acre property in Illinois was accomplished at \$1.84 per acre, whereas ground surveys for a nearby 2045-acre tract with similar terrain cost \$2.92 per acre. Both were mapped at a scale of 1 in. to 100 ft, and the contour interval was 5 ft.

In general maps at a 5-ft contour interval cost about \$1.50 per acre; for a 10-ft interval, \$0.60 per acre or more; for a 20-ft interval, \$0.35 to \$0.50 per acre. Of course, the cost of each mapping must be estimated separately.

Photomaps or mosaics vary in cost too, from 5¢ to 10¢ per acre according to scale and the size and shape of the area. This includes the individual aerial photos for stereo study.

Aerial photographs are the base for both the photomosaic and the aerial topography map. Before the mosaic is assembled, the photos must be *corrected* for minor tilt, which occurs because the airplane cannot be maintained in absolutely level flight. Adjustments are also made for the scale difference in photos. These occur because the mapping plane photographs peaks and valleys from the same fixed altitude so that the peaks appear at a larger scale and the valleys at a smaller scale than actually exists.

Compilation of the photomap is not simply a routine of gluing or tacking the aerial photos to a base. First, grids are plotted on the base or plot board over which the mosaic is assembled. Next, the coordinate positions of the control points are indicated on the board. These control points are marked on the aerial photos, and then the photos are placed in position on the board.

The photographs, however, do not match and fit together perfectly because of the tilt and difference of scale unavoidable in aerial photography. A comparison is made, therefore, of the true distances on the plot board and the distances seen on the aerial photo to establish how much the photo must be tilted, enlarged, or reduced to fit, in true horizontal position in the finished mosaic. After corrected prints have been made, they are marked with the control points and assembled on the plot board, with each photograph placed carefully in its correct position. The composite is then copied as a photo map.

Compilation of the topographic map from an aerial photographic base is a more complex and precise process. After the tilt in the original photographs has been corrected, they are viewed in stereo-plotting devices of great precision. The stereo-plotting instrument gives a third-dimensional view of aerial photographs, and the operator drafts the successive elevations until each pair of photos has been contoured. The individual contoured sheets are then assembled and the finished map tracing is made.

In aerial topographic mapping a minimum amount of ground control is needed. Field-survey parties obtain nine vertical control points for each pair of photos, and the horizontal control is made up of several points established along each flight strip. By using the new Wild theodolite, vertical and horizontal control is run simultaneously.

Rugged area, typical of West Virginia stripping operations, seen from the air.

With the network of ground control and the stereo pairs of photographs, contouring with the stereo-plotting instruments can be done much more rapidly than plane-tabling and interpolating field notes. Moreover, the serial topographic map is more complete, since details such as ponds, buildings, power lines, and fences are recorded. In addition, the maps serve as a base to plot property owners' names, drill-holes, outcrop, and other data.

During recent years the science of aerial topographic mapping has developed so that the maps compiled by these methods meet any civil engineering requirement. Standard specifications provide that 90 pct of all elevations shall be accurate within one-half contour interval, and no part of the map shall be in error more than one contour interval.

The contour interval can be 2, 5, 10, 20, or 25 ft, as required. The smaller the contour interval the more costly the map compilation. Choice of contour interval depends on the terrain and the map's future use. In Utah recently Aero Service Corp. mapped an area partly at 5-ft intervals and partly at 25-ft intervals. A West Virginia concern, on the other hand, felt that 20-ft contours were adequate for their purposes.

Recently the entire state of Kentucky was photographed by air and mapped under an agreement between the USGS and the Agricultural and Industrial Development Board of the State of Kentucky. The maps were completed at scale 1:24000, or 1 in. to 2000 ft, and are published in 7½-min quadrangles, with contour intervals of 40 ft.

Research in Rotary-Percussive Drilling

by E. P. Pfleider and W. D. Lacabanne

ROTARY-percussive drilling is a new method of drilling hard rock. Designed to give variations in thrust, revolutions per minute, and torque ranges, these drills combine the high efficiency of the rotary system in soft rocks with an increasing amount of percussive action in rocks more difficult to fragment.

Fundamentals of the rotary, percussive, and combination systems have been described in detail in various papers—most recently by C. Fairhurst and W. D. Lacabanne[1]—but there is still much basic work to be done on the interplay of actions in the rotary-percussive system to enable the drill designer to achieve the highest efficiencies. Whereas the original units struck light blows of only 15 to 30 ft-lb, adequate for medium hard rocks, the present trend is to piston blows of 50 to 65 ft-lb in order to cope with the granites and other rocks having Shore hardnesses of 75 or more.

Some experts hold that forward thrust should be maintained at precisely the level that permits the bit to rebound free of the rock surface, in order for the bit to rotate through its indexing angle and re-establish contact at exactly the time of the succeeding impact. Such conditions would offer the advantages of fixed indexing, as well as prestressing of the bit against rock prior to impact, without the high edge wear caused by rotational drag. In practice, however, rotational drag offsets these theoretical conditions and is probably an advantage. The stresses created by high thrust and torque often approach the rock competent strength, so that the following high percussive impact causes the prestressed rock to fragment in large chips.

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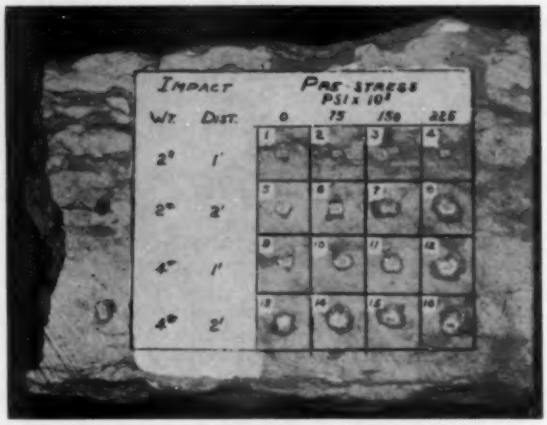
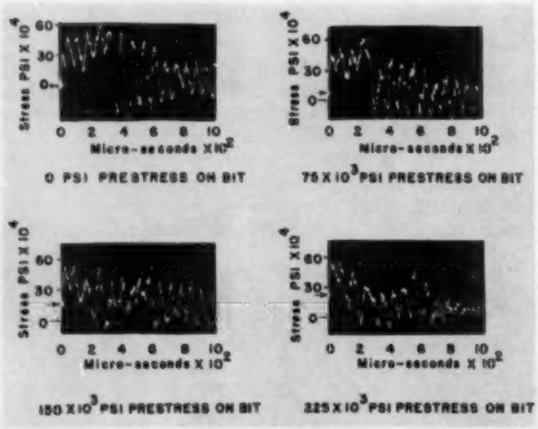


Fig. 1—Craters resulting from variable impact and static forces in Shiely Blue Limestone using 1/8 x 1/16-in. flat bit.

Although the concept of a rotary-percussive unit is not new, commercial development did not commence until 1950-1952, when Muench and Jahn[2] experimented with a Saltzgitter drill in Germany. Field testing was extended by Patzold[3] and Voss[4] from 1952-1955. Inett[5] reported on the progress for the National Coal Board of England, which later purchased several units and began laboratory research with a Hausherr DK 7ES machine. The results of this work were presented by Fish[6] in March 1956. Meanwhile in the U. S. the University of Minnesota School of Mines initiated research in 1953-1954, and this article is a project report to supplement earlier publications.[7] Rotary-percussive units are now being tested at St. Joseph Lead Co. in southeast Missouri and at several other U. S. mining operations with encouraging results.



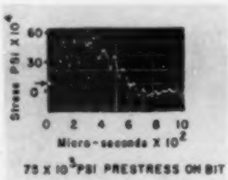


Fig. 2—TOP: Time traces for impact with 1/8x1/16-in. flat bit on limestone (Shore No. = 55). LEFT: Figs. 3a through 3d—Comparison of stress-time traces under variable loading for 1/8x1/16-in. flat bit on limestone rock (Shore No. =55).

Several groups have pushed work using the conventional roller bearing tricone bits. Drilling Research Inc. sponsored basic and applied studies at Battelle Institute[8,9] on vibration drilling, and Hughes Tool Co.[10] conducted experiments using a fluid-actuated rotary-percussive machine in large diameter holes. The Russians made an interesting series of tests with tricone bits on a special stand constructed at the All-Union Oil Drilling Research Institute,[11] featuring rotational speeds from 40 to 475 rpm, thrust from 2500 to 1500 lb, and 2000 to 6000 impacts per min. In all cases reported drilling speeds for rotary-percussion have been 3 to 20 times greater than for straight rotary drills with similar thrusts and rotational speeds.

Principal Factors in Drilling Efficiency

Fundamental Drilling Criteria: Many investigators have studied the principles of fragmenting rocks by percussion. By using a simple drop test, Simon[8] of Battelle Institute and Shepherd[12] of Ingersoll-Rand have arrived at a better understanding of failure mechanism and the relationship between energy levels, velocity of impact tool, and proper indexing. It is natural that the harder rocks require higher impact levels. Simon and Shepherd have shown that there are two primary variables in percussive drilling: 1) impact energy per unit length of chisel edge and 2) indexing distance.

Within the range associated with rock drilling impact velocity has no appreciable effect, aside from the fact that increased striking velocity of a given system raises the energy level of a blow.

From a fundamental analysis of rock fragmentation, Simon develops the following relationship:

$$R = \frac{2.4\,(P - P_t)}{D^2 S}$$

where R = drilling rate.
P = actual power input to the rock ($E_t v$).
P_t = threshold power, the lower limit of energy below which no fragmentation occurs. Actual value of P_t depends on S.
D = hole diameter.
S = drilling strength of the rock.

This relationship shows that for a given drilling situation drilling rate depends *solely* on the power input, i. e., on the rate at which energy can be transmitted to the rock. Many recent developments are aimed simply at increasing this energy input factor.

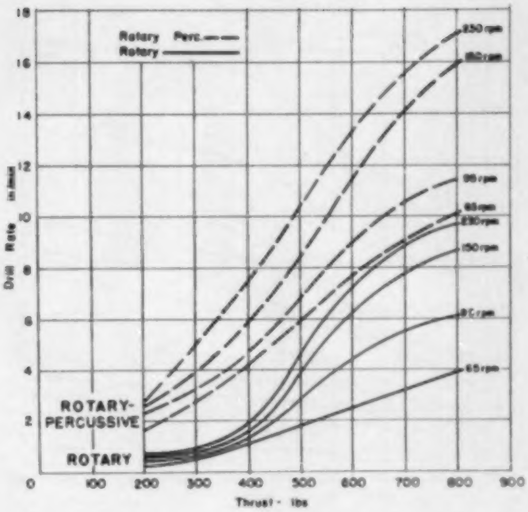


Fig. 4—Effect of thrust on drilling rate. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. Speed of penetration rises somewhat proportionately to thrust for both rotary and rotary-percussive method. Rotary drilling requires about twice as much thrust to achieve comparable rotary-percussive rates.

Although percussive drilling can break the hard rocks, with reasonable bit wear, it is a discontinuous process and much of the energy imparted is lost in rod vibration. Furthermore, bit indexing is somewhat haphazard, and often the bit is not in firm contact with the rock at the time of impact blow because of low thrust levels. As thrust is increased, bit rotation, created by action of the rifle bar, becomes increasingly difficult. A larger percentage of the impacting energy of the piston—or the rebound energy of the drill steel—is required for rotation and the drill unit stalls. All these factors, clearly demonstrated by Inett and Cheetham,[13] explain the inherently poor efficiencies of percussive units.

Failure of strong and brittle rock ahead of a rotary drag bit apparently is caused by a combination of tensile and shear stresses. The magnitude and direction of these stresses depends on 1) thrust, 2) rake angle of leading edge, 3) wear of contact surface, and 4) torque. As rotational speeds are in-

Table I. Relative Volumes of Craters Produced in Limestones with Varying Prestress and Impact Levels on a 1/8 x 1/16-In. Bit

Impact		Prestress Load, Lb / Stress, Psi	0 / 0		600 / 75,000		1200 / 150,000		1800 / 225,000	
Wt, Lb	Drop, Ft	System Energy, Ft-Lb Relative Volumes, Pct	Ft-Lb	Pct	Ft-Lb	Pct	Ft-Lb	Pct	Ft-Lb	Pct
2	1	Static	0.0		0.3		1.25		2.8	
		Dynamic	2.0	2	2.0	2	2.0	5	2.0	5
		Total	2.0		2.3		3.25		4.8	
2	2	Static	0.0		0.3		1.25		2.8	
		Dynamic	4.0	7	4.0	13	4.0	17	4.0	37
		Total	4.0		4.3		5.25		6.8	
4	1	Static	0.0		0.3		1.25		2.8	
		Dynamic	4.0	11	4.0	21	4.0	18	4.0	55
		Total	4.0		4.3		5.25		6.8	
4	2	Static	0.0		0.3		1.25		2.8	
		Dynamic	8.0	51	8.0	52	8.0	58	8.0	100
		Total	8.0		8.3		9.25		10.8	

Relative volume figures represent average of two complete runs on separate pieces of rocks. As would be expected, deviations were rather large, but orders of magnitude were similar in each case. Static loadings of 2400 to 3000 lb (300,000 to 350,000 psi) caused rock failure resulting in craters having a relative volume 40 pct of maximum.

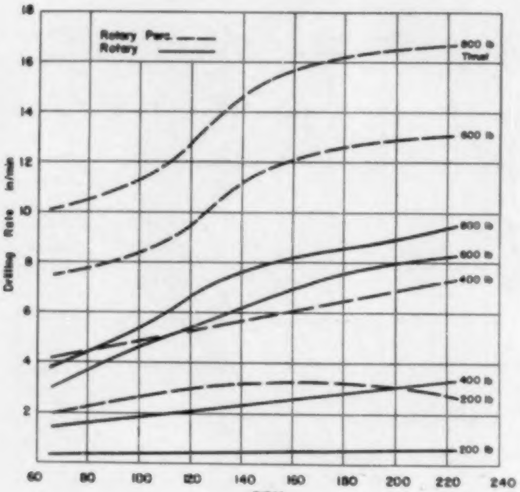


Fig. 5—Effect of rotation speed on drilling rate. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. The rate of improvement in drilling speed falls off in rotary-percussive over 150 rpm. This 150 rpm is equivalent to about 25° of indexing between blows. The German work has indicated optimum indexing for rocks of this hardness, with bit diameters of 1¼ in., to be about 20°. As expected, penetration rate is not directly proportional to rotation speeds at constant thrust for either rotary or rotary-percussive, additional thrust being essential to get efficient drilling as revolutions per minute are increased.

creased at constant thrust, the ratio of thrust to rotating force decreases, the resultant attack angle of the bit is lowered, and the shearing trajectory becomes shallower. This results in fine grinding, decreased rate of advance, and again more bit wear. Thus higher thrust and lower bit speeds become essential as the rocks increase in strength and hardness.

The higher thrusts required by the more competent rocks cause frictional drag and result in bit wear or failure, thereby compounding the problems in abrasive rocks. R. Shepherd[14] in England presents the mechanics of the problem of rotary drilling, and Fairhurst[15] has studied mode of failure using a high-speed camera. Apparently the bit tip deflects as it builds up stresses to point of failure, rock particles fracture, the bit snaps forward again to engage rock, and the process is repeated. Hence a micro-vibrating impact action by the bit tip is achieved during rotation. This condition accentuates tungsten carbide tip breakage, especially in hard rocks.

The rapid rotation of a roller-type cone bit gives a slight impact blow followed by a crushing action. However, the impact level is comparatively low and fragmenting probably depends more on thrust, which again must be very high for the stronger rocks. Hughes Tool Co., of course, has done much research on these types, as reported by Williamson[30] and others.

In all drilling, as in crushing and grinding operations, there appears to be a definite relationship between particle size on one hand and rate of advance and energy consumption on the other. The coarser the particle that can be produced, the faster the advance for a given power consumption. Hartman and Pfleider[27] express the basic equation that for a constant energy input the drilling speed varies directly

Table II. Results of Experimental Runs at 80 Psi Air Pressure

Rock Type	Drilling System	Thrust, Lb	Penetration, In. Per Min	Air Consumed, Ft Per Min	Cu Ft of Air Per Cu In. of Rock
Shale	R-P	1200	60.0	465	3.5
	Rotary	900	60.0	240	1.8
	Percussive	—	—	—	—
Soft Sandstone	R-P	1400	68.0	475	3.1
	Rotary	1300	68.0	255	1.7
	Percussive	—	37.0	195	2.3
Hard Sandstone	R-P	2000	45.0	450	4.5
	Rotary	3200	45.0	265	2.6
	Percussive	—	23.5	175	3.3
Granite	R-P	2700	39.5	475	5.4
	Rotary	5700	39.5	280	3.2
	Percussive	—	19.0	190	4.5

Table III. Physical Properties of Shiely Blue Limestone

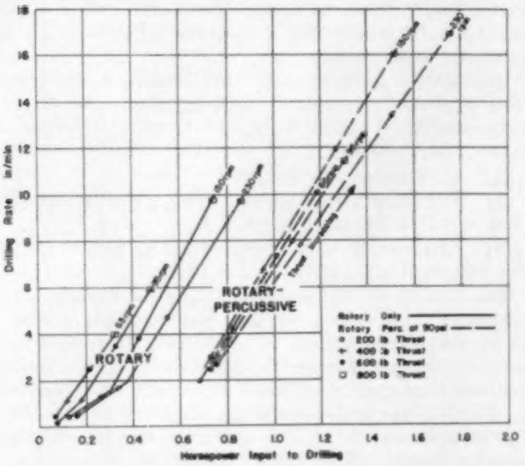
Property	Test Runs, No.	Mean Result	Standard Deviation, Pct
Apparent specific gravity	6	2.70	0.94
True specific gravity	1	2.77	—
Voids	—	2.9 pct	—
Apparent porosity, connected voids	4	1.7 pct	25
Gas porosity	1	0.9 pct	—
Compressive strength perpendicular to beds	2	23,710 psi	18.6
Compressive strength with bed; parallel to strike	4	21,680 psi	2
Shore scleroscope hardness	210	54.5*	12.8
Mohs hardness	—	4.5**	—
Mohs hardness (calculated)	—	4.24**	—
Young's modulus, as determined by axial penetration of small carbide inserts	—	12.3×10^6 psi	—

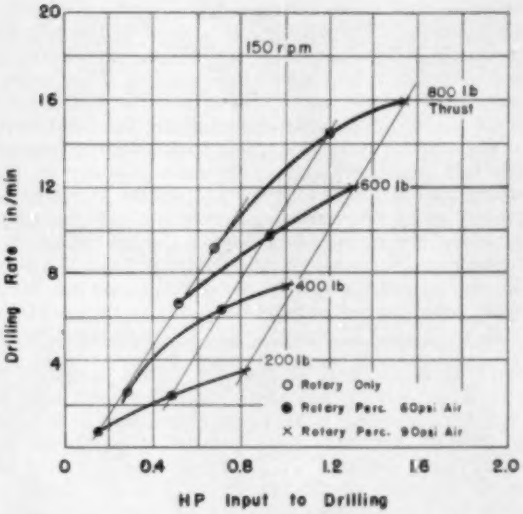
* Shore units.
** Moh units.

as the mean particle size produced, i. e., $S \alpha d$. Good drill design and practice employ this general principle of producing the coarsest particles possible under given conditions. Effective application of percussion is an important factor. In the straight percussive system a large percentage of energy is lost in rebound through vibration and heat. Applying a static loading to the bit face to cause a prestress to the rocks, and then impacting, is much more effective and reduces energy loss through vibration to a minimum. Most engineers in the mineral industry are familiar with the excellent job accomplished by the core splitter in using this principle. It is believed that this combination effect of preloading with impact is particularly important in rotary-percussive drilling. Research on this effect is one of the projects now under way at Minnesota.

Effect of Static Loading on Impact Failure of Rock: A study of the literature reveals that little work has been done on this subject. Charles and de Bruyn[28] made an excellent investigation of energy transfer by impact, using falling weights on an unconfined pyrex rod, but many of the phenomena they describe are altered by prestressing and failure. Research in this area at the Minnesota School of Mines began in 1954; the subsequent period has been spent improving equipment and interpreting results. The experimental set-up, a Carver press of 20,000-lb loading, has impact weights of 1, 2, and 4 lb with falls up to 2 ft. The short bit holder is equipped with SR-4 strain gages, and the Electronix oscilloscope has a Polaroid camera attachment.

The effect of high preloadings is strikingly evident upon examination of the craters produced in the





Figs. 6 and 7—Relationship between horsepower input and drilling rate. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. The rotary system is the more efficient, energy-wise, up to the drilling rates permissible. This is as expected for limestone rock, because intermittent impact energy is basically less efficient than continuous steady thrust energy. At a constant rotation speed of 150 rpm (Fig. 7) penetration rates for similar horsepower inputs increase as thrusts rise and drilling approaches the straight rotary method.

surface of the Shiely Blue Limestone around the 1/8 x 1/16-in. flat tungsten carbide bit. Table I presents the volume of rock fragmented in the craters, indicating a gain of 2 to 5 times when a prestressing of 1800-lb force is applied on the bit as compared to no prestress. Microcracks have been developed in the base of the craters, and these will assist in further fragmentation with successive impacts. Here is a simple but very important mechanism to be incorporated into the design of rock drills.

It is difficult to determine accurately the relative amounts of static and kinetic energy employed to achieve these rock failures, but on the basis of the force-distance concept for both static and kinetic energy the following figures can be obtained by using a Young's Modulus of $E = \frac{\sigma}{\epsilon} = 12{,}000{,}000$ psi as determined for this particular limestone:

Force, Lb	Stress, σ	Strain, Ft, ϵ	Energy, Ft-Lb
600	75,000	0.00052	0.3
1200	150,000	0.00104	1.25
1800	225,000	0.00156	2.8

A study of these interrelated factors may indicate that static strain energy, if above a critical level, can

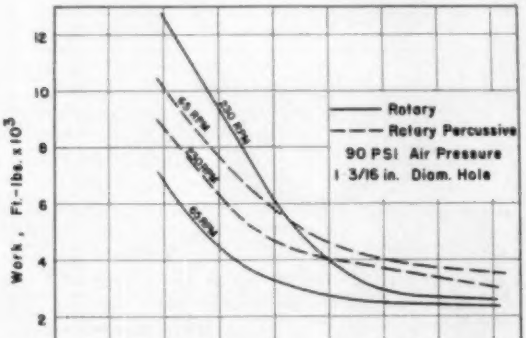


Fig. 8—Drilling efficiency (work required to drill 1 cu in. of limestone). Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. The rotary system at high thrust is the more efficient energy-wise. However, at thrusts of 600 to 800 lb, rotary-percussion requires only about 3000 ft-lb of work per cubic inch of rock drilled as compared to 2500 ft-lb for straight rotary. The advantages of greater penetration rates and less bit and drill rod breakage for the rotary-percussive system more than compensate for this small increase in energy consumption.

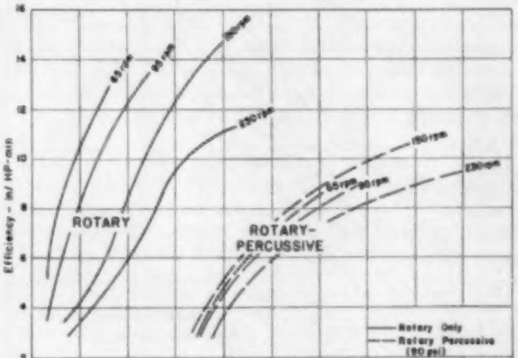


Fig. 9—Relationship between horsepower input and drilling efficiency. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. Drilling efficiency, expressed as inches of hole drilled per hp-min (33,000 ft-lb) increased to a high of 15 for the rotary system at the highest thrust and optimum revolutions per minute. Meanwhile, rotary-percussion attained a comparable figure of 11 in. per hp-min when maximum thrusts of 800 lb were employed.

be somewhat more efficient than a comparable impact energy. This principle is proved in the drilling methods, wherein rotary drilling is preferable to percussive or rotary-percussive drilling if the necessary thrust levels can be maintained without excessively large equipment or damage to bits and rods.

The writers have attempted to isolate the reasons for this impressive effect through a study of the stress-time system as recorded on an oscilloscope screen, using SR-4 strain gages to indicate the magnitude of the transient stresses in the bit holder. Although the stress wave reflections between the ends of the impacting system tend to mask the main stress-time curve,* several factors are evident. Stress level at midsection of the tool holder appears to rise to a plateau dependent on failure strength of rock for cratering, in this case equivalent to 300,000 to 350,000 psi. This failure limit is confirmed by static tests wherein 1) cratering was initiated at static loadings of 300,000 to 350,000 psi (2400 to 2800 lb) for the same 1/8x1/16-in. inserts; 2) oscillating stress waves in the impacted system give vibratory effects, possibly helpful in the fracturing process; 3) time duration of high level impact stresses was fairly constant at 500 to 700 μsec (0.005 sec) for the weights and kinetic energies tested; 4) rebound of falling weight was smallest (½ in. or less) with a 4-lb weight at 2-ft drop where maximum craters were produced. When 8 ft-lb of impact were employed there appeared to be adequate energies and stresses to pulverize and eject the material directly under the bit, rather than to leave as a compressed briquet.

* These complicated stress variations are now under study.

Applied Research in Europe

Much experimental testing and laboratory research is being done in various parts of Europe on the rotary-percussive system. The original works of Jahn,[2] Patzold,[3] and Voss[4] in Germany have already been covered in U. S. publications by Lacabanne and Pfleider[7] and by Inett.[19] These showed the following advantages for rotary-percussive tools in medium hard rocks:

1) Better performance. One Hausherr carriage-mounted unit replaced five airleg percussion drills. Comparable or higher drill rates than rotary drill at much lower thrust.

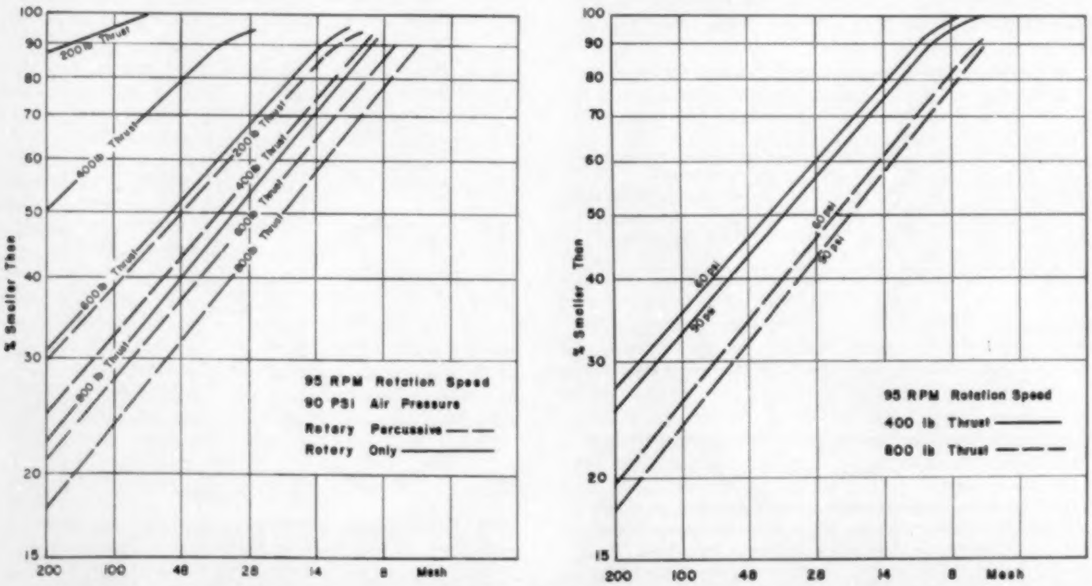
2) Longer bit life in harder rocks.

3) Constant thrust on drill steel, reducing vibration and thus increasing rod life.

4) Coarse size of cuttings, showing higher drilling efficiencies and lower dust hazards.

On the basis of these outstanding results, the National Coal Board of England installed a Hausherr DK 7ES machine in its Mining Research Establishment at Isleworth, Middlesex. The results achieved in shale and hard sandstone, as reported by Fish,[6] confirmed those being obtained on the continent and extended the system into the harder granite series. Significant results of the experimental runs at 80 psi air pressure are summarized in Table II. Surprisingly, the rotary-percussive unit is less efficient than the percussive drill insofar as air consumption is concerned. Changes in drill design, featuring heavier impact blows, hydraulic feed, and electric motors for rotation should correct these inefficiencies. Furthermore, if a mechanical impactor is developed to withstand heavy frequent blows, there should be an appreciable gain in efficiencies.

In Germany the trend[20] is to use drills with percussive energies of 4 m-kg (20 ft-lb) at 2800 blows per min. Research by Jahn and others has shown that higher percussive energies are advisable for the harder rocks, with flexibility for easy change of percussive blows, thrust, and rotational speed. An experimental unit now on trial has percussive en-



Figs. 10 and 11—Effect of thrust and varying impact levels on particle size produced. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. Mean particle size increases from 200 to 20 mesh as thrust is increased and impact added. Generally speaking, particles produced from rotary-percussion are appreciably coarser than by the straight rotary method. Furthermore, particle size increases as impact energy per blow goes up by a change from 60 to 90 psi air. The above phenomena are exactly as would be expected from fundamentals.

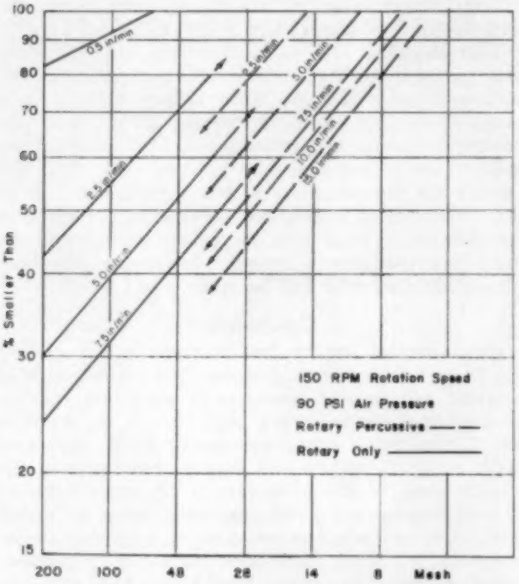


Fig. 12—Relationship between rate of advance and particle size produced. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. Particles become coarser for the higher rates of advance in both systems. Cuttings from rotary-percussion are coarser than for the rotary method at same penetration speeds.

ergies of 9 m-kg (65 ft-lb) at 5600 blows per min, using a double piston device. The high percussive energies of 8 m-kg are not especially hard on carbide bits, according to Jahn, and he expects that values of 10 m-kg will be reached.

An interesting investigation, "Effect of Vibration on Speed of Rotary Drilling of Hard Rocks with Three-Cone Rock Bits," has been made by the All-Union Drilling Research Institute.[11] Test conditions with a mechanical vibratory of eccentrically rotating weights compared as follows with those conducted on the Hughes Percussor:[10]

Item	Russian Tests	Hughes Percussor
R = thrust, lb	(2,600 to 14,500) 4,400	(5,000 to 40,000)
M = momentum, ft-lb	Of eccentric cams (1.4 to 7.5) 1.8	Of mud-activated piston
n = vibration per min	(2,000 to 6,000) 5,000	250 2,000
= rpm	(40 to 475)	60
Bite size	(3¾ to 9¾ in.) 4¾ in.	8¾ in.

Note: Figures in parentheses represent ranges. Single figures are the principal operating parameters.

As would be expected, the small momentum of the eccentric cams of but 1.4 to 7.5 ft-lb, as used in the Russian tests, was inadequate for the size of the bit used. However, the investigation did establish: 1) the fact that drilling rate is proportional to the vertical disturbing force of the vibrator and the static load on bit; 2) the existence of an optimum rotational speed, placed at 75 to 120 rpm, for impact energies and frequencies employed, and 3) the development of an empirical formula to calculate the necessary vibrator parameters that will produce a desired drilling speed under given conditions. Their work was done in limestone, marble, and granite and showed increases in drilling rates 10 to 15 times that obtained without vibration—other conditions being constant.

Applied Research in the U. S.

In the U. S. much study is being given the entire field of rotary-percussive drilling, particularly in the petroleum industry. A case in point is the work of Battelle Memorial Institute for Drilling Research Inc.,[9] using magnetostriction techniques to achieve vibrations of the bit. Borg-Warner is developing an interesting unit that obtains its percussive action through use of the mud flow to revolve unbalanced weights and hence set up a harmonic motion in the drill stem.[12] The Hughes Percussor drill employs a mud-activated piston, weighing 120 lb and striking with a velocity of 12 fps to achieve its 2000 blows per min, rated at about 250 ft-lb of kinetic energy. Prior laboratory and field tests of rotary-percussive drilling gave drilling rates 5 to 25 times greater than those attained with conventional rotary practices. However, mechanical and electrical problems involved in getting the necessary energy to the percussive or vibratory element at the bottom of the hole have hindered commercial development.

Applied Research at the University of Minnesota

The program for applied research at the University of Minnesota is designed to expand the usefulness of the rotary-percussive drill into the field of the extremely hard rocks, specifically taconites and the dense iron ores of the Soudan and Cliffs Shaft type. The procedure for this program includes investigations of:

1) Rocks of limestone types. Study now completed.

2) Rocks of granite type. Study commencing.

3) Rocks of taconite types.

4) Bit design for conventional tungsten-carbide chisel type, using bits of 1¼-in. diam.

5) Bit design and performance for tricone roller type, using micro-bits of 1¼-in. diam.

For the first phase of the program—work on rocks of the limestone type—a 3-hp drill press was modified for rotary drilling experimentation and then equipped with a chipping hammer to add the percussive blows through the quill to the bit edge. Operating parameters of the completed unit are as follows:

Rotary System: Rotational speeds—rpm 65, 95, 150, 230, 400, 575, 900, 1350. Thrusts on bit face—200 to 1200 lb.

Percussive System: Chipping hammer, weighted to 78 lb to prevent bouncing, having the following manufacturers ratings:

Air Pressure	Blows Per Min	Ft-Lb Per Blow	Output, Hp
60	1700	6.5	0.335
70	2000	7.6	0.460
80	2075	8.5	0.535
90	2150	9.4	0.611
100	2225	10.9	0.735

Bits: Rotary-percussive type of 1 3/16-in. diam, a leading rake angle of 20°, a clearance angle of 30°, and an included angle for cutting edge of 80°.

The drill unit has been instrumented to give continuous recordings of penetration rates and average rotary torque at bit face. Holes are usually drilled 2 to 4 in. deep, and all cuttings are collected for

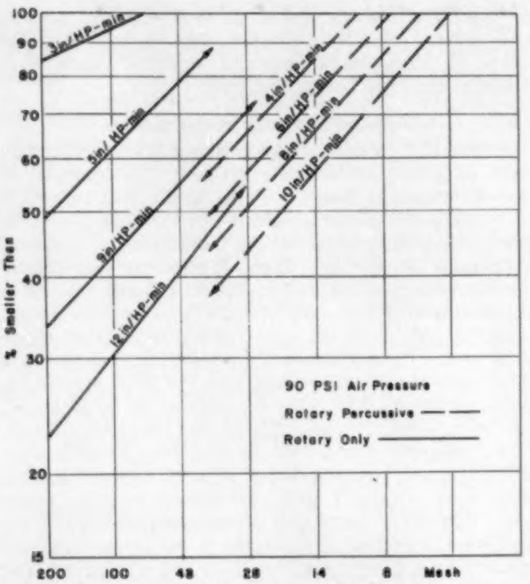


Fig. 13—Relationship between drilling efficiency and particle size produced. Drilling study on Shiely Blue Limestone (Shore No. = 55) using 1 3/16-in. rotary-percussive type of bit. Drilling efficiency for the rotary method increases rapidly as the mean particle size changes from 200 mesh (5 in. per hp-min) to 28 mesh (12 in. per hp-min). The same holds true for rotary-percussive drilling. Again, rotary-percussive drills must and do fragment the rock considerably coarser to achieve comparable drilling efficiences. For example, for 10 in. per hp-min rotary-percussion produces mean particle sizes of 20 mesh as contrasted to 48 mesh for rotary.

particle size analysis. The horsepower figures presented in the discussion of drilling efficiencies are calculated according to the following criteria:

$$\text{Rotary hp} = \frac{\text{Torque table reading x rpm x } 2\pi r}{33{,}000}$$

Percussion hp = 0.611 hp at 90 psi air, as per manufacturers rating of impact energy per blow and blows per minute. For example:

$$\text{Percussive hp} = \frac{\text{Ft-lb per blow} \times \text{blows per min}}{33{,}000} = \frac{9.4 \times 2150}{33{,}000} = 0.611.$$

Total horsepower for the rotary-percussive system equals the sum of the above two.

Test Results: The purpose of the investigations was to compare the various characteristics of rotary-percussive drilling with rotary drilling in a tough limestone rock. A Shiely Blue Limestone having the physical constants noted in Table III was used. This is a dense, fine-grained rock, and test results are reproducible within a range of 5 to 15 pct. Shiely Blue Limestone represents a rock type too difficult to drill with the rotary equipment and drag bits available at present because of the high thrust requirements and bit wear.

Conclusions

Fundamental and applied research in Europe and the U. S. has demonstrated that the combination of rotation and impact forces is an excellent method of drilling rocks requiring high thrusts on the drill bit. Commercial rotary-percussive drills, currently produced in Germany and France, have proved the effectiveness of the principle. U. S. manufacturers are developing units and preparing them for initial tests. Certain advantages, generally giving better overall efficiencies, have been indicated or proved: faster penetration rates, longer bit and rod life, and coarser cuttings.

If this new tool is to reach its full effectiveness in the very hard rocks, however, various problems still require intensive research. The universities, the drill manufacturer, and the mining companies should cooperate to investigate thrust requirements, optimum impact blow, and bit design. Efficiency of energy consumption could be improved appreciably if a durable and compact system of mechanical impact can be developed, or if hydraulic or electric power sources are employed for thrust and rotation. There should be detailed investigation of static prestress coupled with impact energy in creating rock failure.

Acknowledgments

The authors wish to acknowledge the valuable assistance given them by associates at the University of Minnesota and by coworkers in the field both here and in Europe. The phases of the investigation were sponsored by a special grant of the Minnesota Institute of Research through the Graduate School of the University, as well as by the U. S. Bureau of Mines Fellowship in Drilling. The special bits were provided by Kennametal Co. without charge.

References

[1] C. Fairhurst and W. D. Lacabanne: Some Principles and Developments in Hard Rock Drilling Techniques. *Proceedings*, Sixth Annual Drilling Symposium, University of Minnesota, Oct. 11-13, 1956.

[2] R. Jahn: Das Drehschlagbohren. *Gluckauf*, Sept. 11, 1954, vol. 90, no. 37/38, pp. 1086-1093.

[3] F. Patzold: La Foracion Vibrée. *Revue de l'Industrie Mineral*, Jan. 12, 1953, vol. 34, no. 602, pp. 1058-1065.

[4] K. H. Voss: Kritische Untersuchungen und Betrachtungen uber das Drehschlagbohren. *Bergfrecheit*, October and November 1954, vol. 19, nos. 10 and 11, p. 413.

[5] E. W. Inett: High Speed Drifting in the Ruhr Coalfield with Special Reference to Drilling Techniques. *Trans.*, Institute of Mining Engineers, London, November 1954, pp. 146-149.

[6] B. G. Fish: Percussive-Rotary Drilling. *The Mining Magazine*, March 1956, pp. 133-142.

[7] W. D. Lacabanne and E. P. Pfleider: Rotary-Percussion Blasthole Machine May Revolutionize Drilling. MINING ENGINEERING, September 1955, vol. 7, no. 9, pp. 850-855.

[8] R. Simon: Theory of Rocks Drilling. Presented at Sixth Annual Drilling Symposium, University of Minnesota, Oct. 11-13, 1956. To be published in *Proceedings*.

[9] J. V. Pennington: Rock Failure in Percussion. *Petroleum Engineer*, May 1954, vol. 26, no. 5, pp. B-76.

[10] W. H. Cline, Jr.: Progress Report on a Fluid Actuated Rotary-Percussion Engine. Presented at Petroleum Mechanical Engineering Conference, ASME Meeting, Houston, Tex., Sept. 28, 1953.

[11] E. I. Tagiyev, D. D. Barken et al.: Effect of Vibration on Speed of Rotary Drilling of Hard Rocks with Three-Cone Rock Bits. *Neftianoe Khaziaistvo*, 1955, no. 9, pp. 20-28.

[12] B. F. Shepherd: The Connecting Link in Percussion Drilling. *Mining Congress Journal*, November 1954, vol. 40, no. 11, pp. 28-31.

[13] W. Cheetham and E. Inett: Factors Affecting the Performance of Percussion Drills. *Trans.*, Institute of Mining and Metallurgy, 1953-54, vol. 63, part 2, no. 584, pp. 45-74.

[14] R. Shepherd: Rotary Drilling. *Proceedings*, Fifth Annual Drilling Symposium, University of Minnesota School of Mines and Metallurgy, October 1955, pp. 39-52.

[15] C. Fairhurst: Some Possibilities and Limitations of Rotary Drilling in Hard Rock, *Trans.*, Institute of Mining Engineers, vol. 115, part 2, pp. 85-103.

[16] T. N. Williamson: Use of Tungsten Carbide in Roller Cutter Rock Bits. *Proceedings*, Fifth Annual Drilling Symposium, University of Minnesota School of Mines and Metallurgy, October 1955.

[17] H. L. Hartman and E. P. Pfleider: Exhaust Dust Control in Dry Percussion Drilling. Part I—Formation of Cuttings. *AIME Trans.*, MINING ENGINEERING Special Report Series, 1955, no. 1.

[18] R. J. Charles and P. L. de Bruyn: Energy Transfer by Impact. *AIME Trans.*, January 1956, vol. 205, pp. 47-53.

[19] E. W. Inett: Rotary-Percussive Drill Studies Explain New Drilling Technique. *Engineering and Mining Journal*, August 1956, vol. 157, no. 8, pp. 75-79. Also in *Proceedings*, Fifth Annual Drilling Symposium, University of Minnesota School of Mines and Metallurgy, October 1955.

[20] R. Jahn: Personal communication, March 9, 1956.

[21] A. G. Bodine: Sonic Drill Versatile. *Oil and Gas Journal*, June 27, 1955, no. 54, p. 74.

Automatic Controls and Milling Operations

by H. E. Uhland and W. Barbarowicz

AT the Noralyn mine and mill of International Minerals & Chemical Corp. in Bartow, Fla., process instrumentation has been incorporated in three departments—mining, flotation, and preparation.

Use of the dragline is the most difficult aspect of the mining operation to control automatically. At the Noralyn mine there are two draglines, a Bucyrus-Erie 1250-B with 29-yd bucket and 235-ft boom and a Bucyrus-Erie 1150-B with 21-yd bucket and 215-ft boom. These are equipped with a minimum number of instruments, but further instrumentation would increase the operator's efficiency.

Some time ago Dunlap & Associates made a survey of the dragline operation. As a result of this survey, a new type of cab was designed with instruments to guide the operator. These include:

1) Two potentiometers and a computer to measure bucket elevation.

2) A pair of Selsyn motors with gear train driven from the dragline swing motor to measure the dragline swing angle.

3) Another pair of Selsyn motors to measure the distance of the bucket from the dragline base.

4) Limit switches and alarms on both hoist and drag cables.

5) Measurement amperes on the hoist motor to indicate the tons hoisted in each bucket.

6) A voltmeter so that the machine may be shut down if voltage drops to a dangerous level.

7) A Panalarm system to give audible and visual warning of malfunctioning of many operating accessories.

This is not the ultimate for instrumentation on a dragline. When an entire operation depends on a piece of equipment costing well over $1 million, there is need for further study.

Pump System: As shown in the accompanying sketch, the dragline at Noralyn dumps the phosphate matrix into a well. A 16x48-in. dredge-type centrifugal pump picks up this matrix from the well

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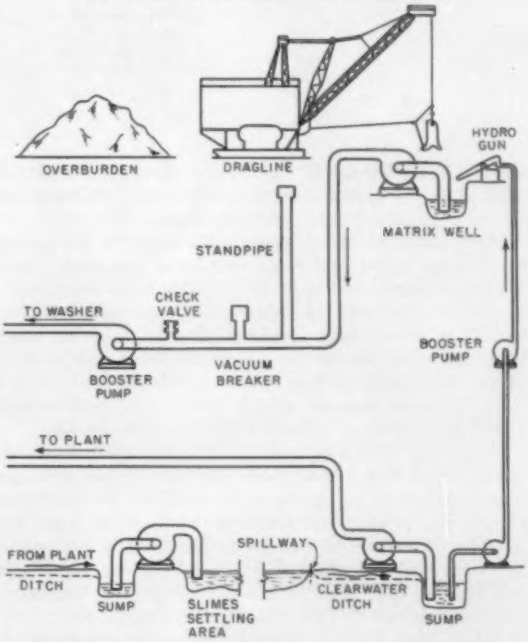
MINING DEPARTMENT OPERATIONS

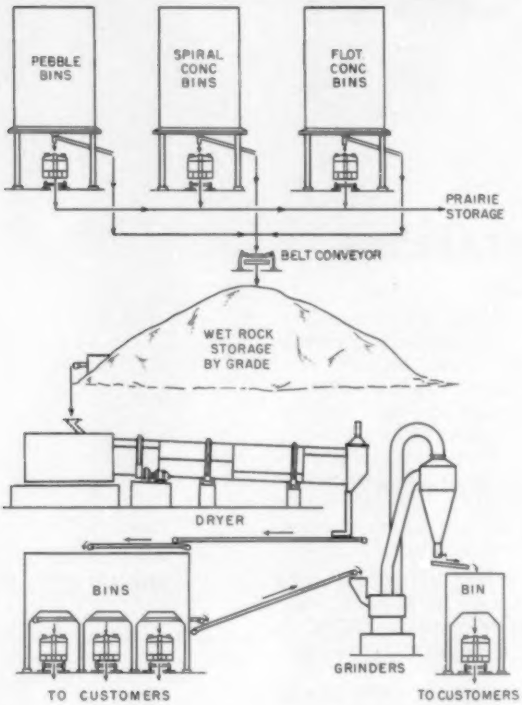


and, with the aid of booster pumping stations, pumps it to the washer, which can be as far as eight miles away. Normally about 9000 gpm of slurry are pumped at densities from 1.20 to 1.5. As much as 1500 equivalent dry long tons per hr of matrix are pumped to the washer.

At one time manually operated hydraulic guns were used at the pit to slurry the phosphate matrix so that it could be pumped to the washer. No man has the strength and stamina to operate one of these guns for 8 hr at maximum efficiency, especially in bad weather. They have been replaced by remotely controlled guns, and more uniform and increased pumping rates have been achieved.

As the matrix is pumped from mine to mill, pressure transients of such magnitude are generated that

PREPARATIONS DEPARTMENT OPERATIONS



they frequently burst the pumps. Vacuum breakers and pressure relief valves in the pipeline have reduced transients to a safe magnitude.

All pumps in the system, including the pit pump, are driven by wound rotor motors at variable speed. Where volume and specific gravity vary frequently over wide ranges, pumping solids presents a major problem, once necessitating an operator at each booster pump along the pipeline. Over a period of years the company has developed completely automatic booster pumps, which start, stop, and change speed according to pressure on the suction side.

Pumping abrasive solids through the pipelines wears them out rapidly, but the life of the pipe can be extended by as much as 50 pct if it is rotated at proper intervals, since most of the wear is along the bottom. Pipeline thickness is now being measured by a Branson Audigage so that rotation schedules can be set up. This is a high-frequency measurement, made while the system is in operation.

It has been agreed that a meter is needed to measure the amount of solids pumped to the plant. This can be done with a flow and specific gravity measurement. In lines handling highly abrasive material it has been found impractical to use orifices and pipeline taps, which quickly wear down, resulting in erroneous readings. There has also been great difficulty purging taps in the lines where solids density varies rapidly.

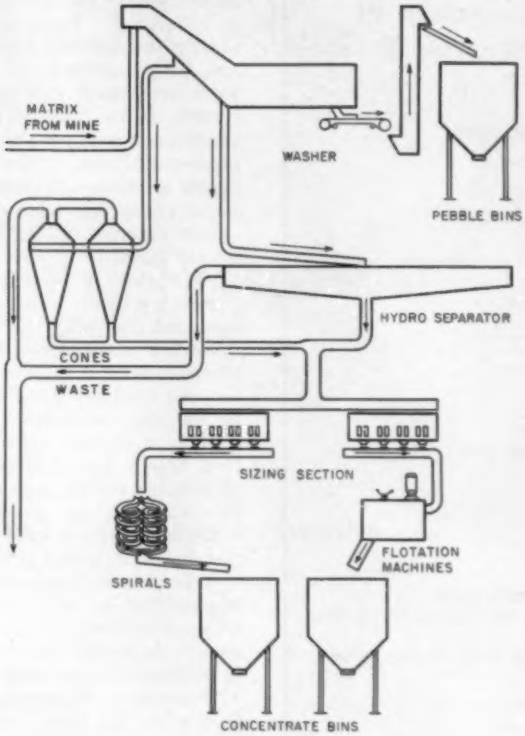
With the perfection of the electromagnetic flowmeter, which does not have taps into the line, and the gamma ray density cell for measuring specific gravity of the slurry, it will be possible to construct a solids meter that is satisfactory. The Foxboro Co. has built a simple computer circuit to take the information from these two meters and convert it to equivalent long dry tons per hour. Recording meters take down the amount and specific gravity of the slurry and the equivalent long dry tons per hour. This information, telemetered to the washer, indicates pit performance and also prevents pumping into a broken pipeline. Since the pit is remote from the washer, it would otherwise be possible to lose the entire production by pumping to a broken line.

In the foreseeable future slurry will be pumped eight miles to the plant, and there will be as many as ten boosters between the pit pump and the washer. At times there will be difficulties along this system, and the company is considering installation of a telemetering equipment at the last booster pump to relay information to the pit pump. Improper functioning anywhere along the system would be reflected by data measured at the last booster pump, namely, discharge pressure, suction pressure, speed of pump, power consumed by the pump, and loss of sealing water at that pump as indicated by an alarm circuit.

Water for hydraulic pressure is obtained from a remote location in the mining area. A stage pump and several booster pumps are necessary to develop pressure required at the pit. At the present time these are operated by remote control. The priming difficulty originally encountered has been solved by placing a standard sump pump on the suction of the stage pump. The sump starts up on shutdown of the stage pump, adding water to the hydraulic system to make up for leakage and other losses in the system which would cause loss of prime.

Waste Disposal: As shown in the flowsheet, the mining department is charged with disposal of waste, which consists of slimes from the flotation plant and tailings from the flotation and spiral sections of the mill. The slimes settle out of the water very slowly, amounting to some 500 acre-ft per month after compaction. Huge retaining dams con-

FLOTATION DEPARTMENT OPERATIONS



tain these slimes until they settle, and the clear water is later discharged into streams or sent through spillways to the recirculating water system for use in the mine and plant. Thousands of dollars are spent each year to avoid stream pollution, and spillways are patrolled each shift, but there is always the possibility that some spillway will discharge cloudy effluent. The company is developing unattended slime detector stations for the effluent of each spillway.

Tailings from the flotation and spiral sections of the mill are often used to build and reinforce dams for retaining slimes, but if improperly controlled they spread over too large an area, filling the space intended for slimes. The slope of the tailings dams can be controlled by regulating the slurry density.

It is planned to dewater the tailings near the end of the dam and then repulp to a fixed density to obtain the desired slope. The company is also experimenting with the addition of controlled amounts of slime and coagulants to form a seal in the tailings dam. Flowmeters, density meters, and proportioning instruments will be used in this program.

Flotation Department: A pictorial flowsheet of the washer, sizing, flotation, and spiral sections of the mill is shown here. At present the only automatic devices in the washer are the liquid level controls on the hammermill sump motor. Electrodes and relays are used to sound alarms and vary the speed of the wound rotor motor by means of contactors.

Several instruments are associated with the 175-ft hydroseparator, which separates the slimes from the mill feed. Most of −150 mesh material is clay and overflows the hydroseparator. Underflow is controlled by a density measurement that regulates the speed of the underflow pump. Elevation of the rotating rakes is controlled by ammeter readings on the drive motors of the rake arms. When the rake arms deflect, as they frequently can, an alarm system warns the operator, who then reduces the mechanical loading of the arms by raising them manually.

At present the only instrumentation in the sizing section is a level control that varies the speed on a sump receiving the underflow from the 85-ft hydroseparator. To improve operation of the Akins classifiers, specific gravity measurements are being made of the overflow.

There are two products from the sizing section—the flotation feed, which is −35+150 mesh, and the spiral feed, which is −16+35 mesh. The flowsheet splits at this point.

The flotation feed is pumped into ten feed bins. Each feed bin, in turn, is pumped into either one of two surge bins that feed the flotation section of the plant. From these surge bins the flow moves into a Dorr rake classifier, onto a conveyor belt and to the reagent mixers, and then into flotation cells. Feed entering the classifiers is controlled by air-operated valves from intelligence obtained in the rake classifiers by specific gravity measurements. This is done in order to put a maximum uniform load on the flotation feed belt. As plant feed goes up the conveyor belt it is weighed by a Merrick Type W weightometer. This weightometer has a rateograph that records and integrates the total weight passing over the belt.

The conveyor belt drive motor has a thermal converter, the output of which is fed to an electronic controller. The controller puts out an air signal, which in turn positions the index setting of reagent flow controller indicators and integrators. In this manner the amount of reagents is proportioned to the plant feed rate.

Mine and Mill Operation at International Minerals & Chemical Corp.

Mining Department

1) Stripping of overburden
2) Mining of matrix
3) Pumping matrix to washer
4) Waste disposal
    A. Slimes settling
        1. Building of dams and ditches
        2. Control of spillways for clear effluent
    B. Tailings
        1. Dam building
        2. Disposal
5) Recirculating water system
    A. Mine use
    B. Mill use
    C. Discharge to streams

Flotation Department

1) Operation of washer
2) Desliming of feed
3) Sizing of feed
4) Beneficiation of feed
    A. Spirals
    B. Flotation

Preparation Department

1) Storage and shipment of concentrate and pebble
2) Blending of phosphate to meet customer specifications
3) Drying of phosphate
4) Grinding of phosphate
5) Shipment to customers

Most of the reagent flowmeters are flowrators. Recently positive displacement metering pumps have been installed on several of the reagents. In all cases the speed of the drive mechanism on positive displacement pumps is controlled automatically or remotely. A speed indicator shows the flow rate, and a stroke counter gives the total flow over any specific period.

In the rougher and amine sections pH measurement and control are used. Electronic instruments regulate addition of caustic to the rougher cells and addition of sulfuric acid to control pH in the amine circuit.

Steam heating is used for some reagents to maintain constant viscosity and optimum flow conditions. In these cases there are usually self-operated temperature regulators. Until very recently the amount of reagent in tanks in the reagent farm was determined by floats. Now bubble tubes determine the level of the reagent in the tank by means of a back pressure measurement, which can be transmitted to a remote location.

Operation of the flowrators has not been entirely satisfactory. There are several reasons for this, including variations in specific gravity and viscosity of the reagents. The flowrators themselves are frequently fouled. To overcome these difficulties, and to improve plant performance in general, there is a constant search for better methods of controlling reagents. The move to positive displacement pumps to feed reagents has resulted in more accurate measurement, but maintenance on the pumps has been greater than expected. The company is now considering electromagnetic and ultrasonic flowmeters for some of the reagents, as these instruments offer no impediment to the flow.

Performance of the flotation plant depends largely on the skill of the operator and the attention he pays to his duties. Two instruments need development to help the operator. The first of these is a continuous BPL analyzer. If an adequate BPL analyzer were developed, it would be placed in the tailings system of the plant. The second, an acid-insoluble analyzer, would be placed in the stream of the final product. Under active development, both instruments offer an advance toward a completely automatic phosphate recovery plant.

Instrumentation in the spirals section of the recovery plant is chiefly the automatic control of reagents. Both flowrators and positive displacement pumps are used. In all cases, the reagent set point is operated manually.

Future Automation in the Recovery Plant: The ultimate goal is measurement of variables throughout the recovery process. These measurements will be fed into a computer, which in turn will feed out signals to various control components in the plant. It is hoped that difficulties can be anticipated and eliminated before they arise. The plant will always be operated at maximum efficiency, obtaining maximum recovery. A data processing system is visualized that will either print out the data on a log sheet or record it on magnetic tape. Certain data will be transmitted by wire to the accounting department, where it will be fed into the IBM punched-card accounting system. Periodically the cards will be used in making out production reports.

Preparation Department: Instrumentation associated with the drier consists of recording pressure gages on the boiler used to heat the fuel oil for the drier and recording draft and temperature gages on the drier itself. Discharge gas temperatures and discharge rock temperatures are measured and recorded by thermocouples and electronic recorders. The operator, for the most part, controls the feed rate into the drier to obtain the proper discharge product moisture. He does this chiefly by the dry rock temperature.

Further improvements could be made. The flame pattern and burning of fuel oil would undoubtedly be improved by viscosity controls. Instrumentation is required to protect the furnace refractories. Perhaps the most needed instrument is a continuous moisture analyzer in the discharge product itself. If this could be found, the data would be used to vary the feed rate and/or speed of the drier. Tests are being made of a dielectric device for measuring the moisture content, with corrections for temperature and bulk density.

Wet rock storage facilities offer a challenge for automation and data processing. In the not too distant future there will be an automatic system of weighing rock, discharging it on the proper storage pile, and reclaiming it by means of controlled feeders to meet the customer grade specifications. This data will be processed automatically and, again, telemetered to the accounting department, where it will be immediately recorded on the IBM punched-card system. Reports will be issued as required.

Chief feature of the grinding system is a fully automatic method of feeding either or both grinders from one or more bins with the same or different products over a conveyor system. To set up his system the operator merely flicks a switch in a selector panel. To improve the grinder operation, continuous samplers and automatic test sample screening are required.

Apparatus and Procedure for Electromagnetic Prospecting

Surveys are effective, speedy and inexpensive.

by D. G. Brubaker

IN the history of geophysical exploration by the electromagnetic method many procedures and types of equipment have been used. Source arrangements for surveying on the ground have included long wires grounded at both ends, large loops laid on the ground, small horizontal loops, and vertical loops of moderate to small sizes. Receivers have ranged from simple direction-finding coils to combinations of coils and a bridge circuit to measure quantities related to both amplitude and phase of the received signal.

Primary considerations in choosing a survey method are effectiveness, speed, and economy. In work on the ground in which locating and outlining conducting bodies is the objective, methods using a vertical coil and a simple direction-finder have been found the most satisfactory. Mason[1] and his associates applied such a method by setting up a vertical source loop, fed with low frequency alternating current by an engine-generator set. With a direction-finding receiver they surveyed lines along the ground in the plane of the loop, taking measurements at each station of the azimuth and inclination of the magnetic field direction. Deviations of this direction from the normal direction, that is, from horizontal and perpendicular to the traverse line, indicated a conducting body. Recent advances in design of light-weight generating equipment have encouraged using this and similar methods.

In 1950 W. H. Westphal and the present writer developed a variation of this method and the apparatus for carrying it out. Their ideas were also based on experience with the Boliden Mining Co. method, which uses a small source coil and a vacuum tube oscillator. The new procedure uses a small vertical source coil, powered by a vacuum tube oscillator, and a direction-finding receiving coil. Source and receiver are kept a fixed distance apart and move as a unit along the survey lines. At each receiver station only the inclination of the magnetic field created by the source is measured.

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TP 4506L. Manuscript, Aug. 7, 1956.

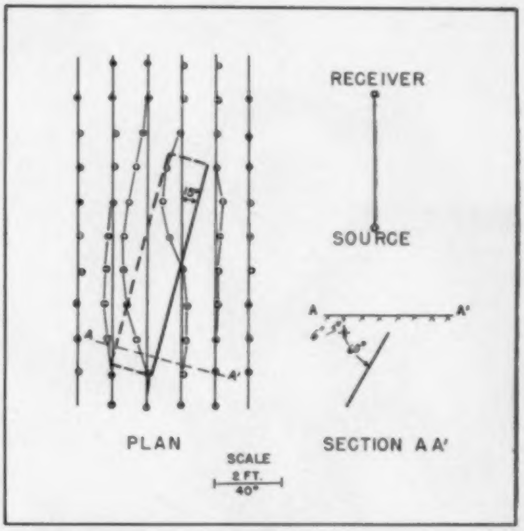

Fig. 1—Results of scale model in-line survey over a metal sheet dipping at 60°. Inclination of magnetic field from horizontal is plotted. Points are of receiver positions.

Source Unit: The source coil and a small vacuum tube oscillator together weigh about 45 lb. The source coil consists of about 60 turns of 10-gage

The Transactions papers appearing in MINING ENGINEERING during 1957 will subsequently appear in AIME Transactions Volume 208 and may be permanently referenced to that volume.

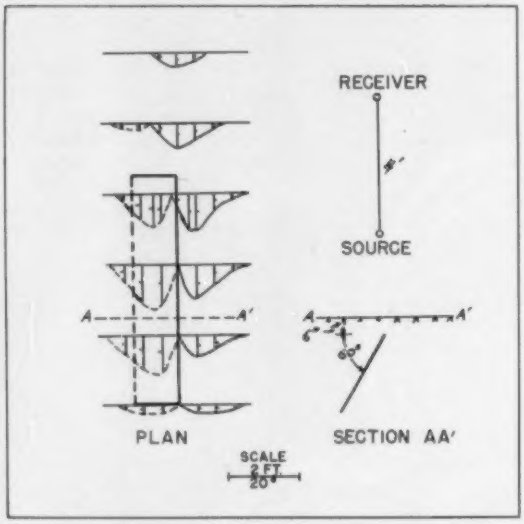

Fig. 2—Results of scale model broadside survey over a metal sheet dipping at 60°. Inclination of magnetic field from horizontal is plotted. Points are at receiver positions.

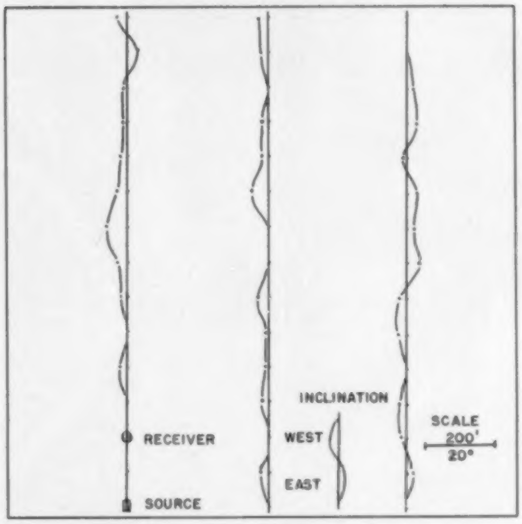

Fig. 3—Part of survey by the in-line method over lines perpendicular to strike.

aluminum wire wound on a rectangular form 10 sq ft in area supported by four spokes of plywood extending from a hub. The hub is offset above the center of the rectangle and padded to permit convenient carrying on the operator's shoulder. The hub also carries a level, set perpendicular to the loop plane, which indicates when the loop is vertical, as well as a compass used for orientation when sighting a line is not possible.

The alternating current for the source loop, of frequency in the 500 to 2000-cps range, is produced by a simple vacuum tube oscillator contained, with its batteries, in a metal box on a pack frame. The box contains all the oscillator components except the loop and its tuning capacitor. The capacitor is inside one of the upper spokes of the loop support. A control switch for the oscillator is also located on this leg.

For work in areas near the interfering noise of power lines, some of the source units have been equipped with clockwork-driven switches with which the oscillator output can be pulsed at about 1 per sec. This makes the signal tone as heard in the receiver easier to distinguish from other sounds.

Receiver Unit: The 16-lb receiver unit consists of about 500 turns of wire on a 13-in. diam form, together with an amplifier and headphones. The coil is tuned to the frequency of the source by a capacitor in its junction box. For work in unpopulated areas, where there are no power lines, untuned amplifiers of the hearing-aid type are used. In other areas, amplifiers are tuned to the source frequency.

The receiving coil is used to measure the angle of inclination from the horizontal of the magnetic field produced by the source. To make this possible, a pendulum inclinometer is attached to the coil.

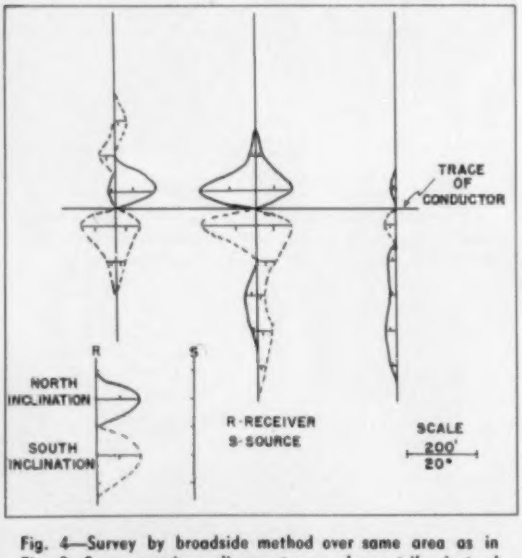

Fig. 4—Survey by broadside method over same area as in Fig. 3. Source-receiver alignment now along strike instead of perpendicular to it.

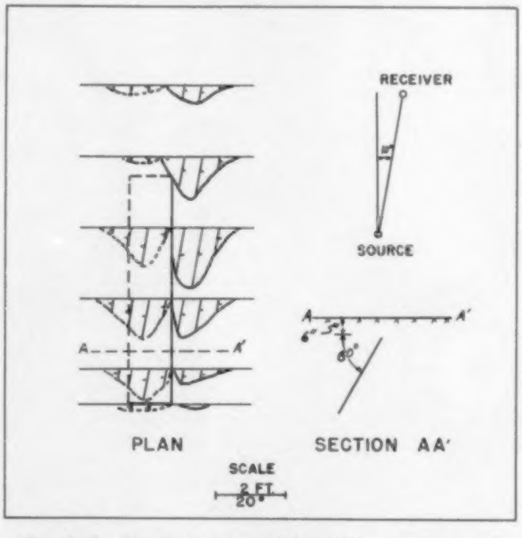

Fig. 5—Results of scale model broadside survey over the metal sheet of Fig. 2. Source-receiver alignment 10° off strike. Data plotted at receiver positions.

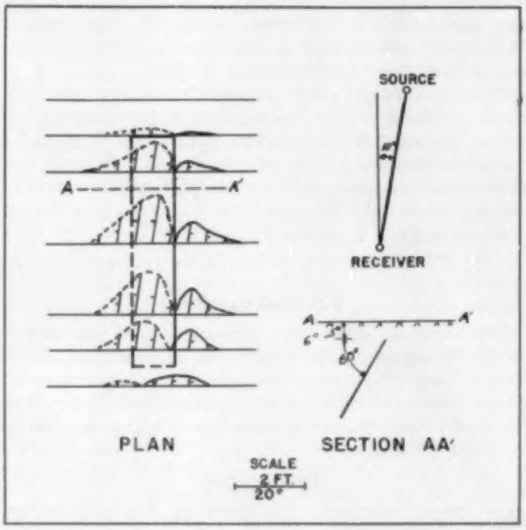

Fig. 6—Results of scale model broadside survey over a metal sheet as in Fig. 5, but with source and receiver interchanged.

The oscillator produces enough signal strength from the source to allow measurement of inclination angles with about 1° precision with a source-receiver separation of 400 ft. This separation is large enough to give effective low cover in areas like the Canadian Shield. It is small enough to allow ready communication between operators, which has been found desirable.

Operation: Two procedures are used. In one, known as the in-line method, source and receiver travel in tandem along the same line, maintaining the standard separation. Measurements are made at 100 or 200-ft intervals. During a measurement the plane of the source is oriented to pass through the receiver station. The survey line is usually at an angle of 30° to the expected direction of orebodies, as a compromise between efficient coverage of the area involved and maximum excitation of buried conductors.

In the other procedure, known as the broadside method, the lines are run perpendicular to the expected strike direction and 400 ft apart. Source and receiver move along adjacent lines, maintaining the source to receiver line along strike.

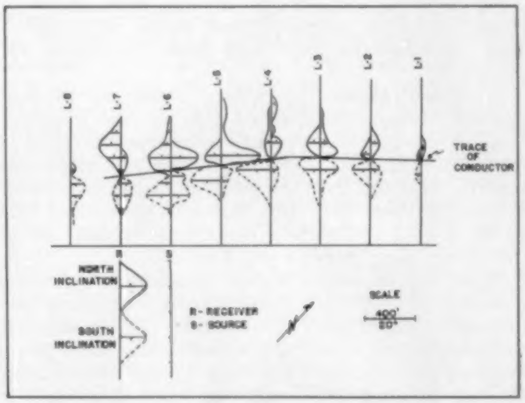

Fig. 7—Anomaly over a steeply dipping graphitic conductor, showing the effect of a change of strike. Data on lines 1 to 3 indicate dip to the northeast.

The in-line procedure has been found especially useful, since it can be used without the cutting and staking of lines that is necessary in many other methods. In clear or lightly timbered areas the entire survey can be performed by a two-man crew, with the receiver operator in the lead running the line by pace and compass. In heavy timber it has been found convenient for a third man to run and mark the line, cutting only as much as is necessary. Rate of surveying has been found to be from 8000 ft of line per day in thick woods to 12,000 ft or more in lightly timbered areas.

An example of the kind of anomaly obtained by the outline procedure is shown in Fig. 1. This is a reproduction of data taken with a scale model apparatus. The conductor was a metal sheet 6.5 x 2.5 ft. Its top edge was 6 in. below the traverse line, its strike direction 15° from the traverse direction, and its dip 60°. The source-receiver separation used was 4 ft. Data are plotted at the positions of the receiver.

The broadside procedure is used for detail surveys over conductors already discovered, or for surveys in heavily timbered areas where line cutting is necessary or where lines are to be cut for other purposes. Because of the previously cut and marked lines, rate of progress by this method may be 15,000 ft or more per day. Scale model data in Fig. 2 illustrate the kind of results obtained.

As before, data are plotted at the receiver positions. For clarity in plotting, the amount of the magnetic field inclination at a given receiver position is represented by the length of a line drawn from that position toward the source position, and the direction of this inclination is shown by a flag on the side of this line. The tips of the lines are connected by envelope curves, solid or dashed according to the direction of the inclination. The point of inclination is then marked by a cusp. It may be noted that the length of the anomaly pattern is about equal to that of the conductor plus the source-receiver separation.

Effect of Alignment on Anomaly Strength: Surveys are made with source-receiver alignment either along the strike direction or not more than 30° off. Consideration of the geometry of the field from the source indicates that the anomaly produced by a sheetlike body should decrease rapidly for larger angles off strike.

A case in point occurred in a survey over an area shown in part by Fig. 3. In this area lines already cut in a north-south direction were used for a survey by the in-line method. There is little evidence of the presence of a conductor in the data of Fig. 3, in which the small deviations from zero inclination do not differ greatly from those generally found over the entire area surveyed.

Later the area was covered by a broadside survey on the same lines. In this survey the source-receiver alignment was east-west. The data, reproduced in Fig. 4, contain a prominent set of anomalies indicating the presence of a shallow conductor. The strike direction of the conductor is at right angles to the direction of the traverse lines, a fact which explains why so little evidence of the conductor was found in the original survey.

Effect of Alignment and Dip of Conductors on Anomaly Character: The scale model studies that have been made show some interesting features of

the data that may be obtained by the procedures described. One of these features is illustrated in Figs. 4, 5, and 6. These show model data taken with the metal sheet of Fig. 4, but in Figs. 5 and 6 the source-receiver alignment is 10° off strike. The arrangement is the same in Figs. 5 and 6 except that in Fig. 6 the positions of source and receiver are reversed.

In Fig. 5 it is seen that the maximum measured inclination to the right of the top edge of the conductor (footwall side) is greater than that to the left (hanging wall side) whenever the traverse line on which the source moves passes over the conductor. When the receiver passes over the conductor but the source does not, the inclinations to the left of the top edge are greater.

Fig. 6 shows that with positions of source and receiver interchanged, the inclinations to the left of the top edge are larger as long as the receiver passes over the conductor.

When the alignment of source and receiver is along strike, the direction of dip of the conductor can be deduced. (See Fig. 5.) However, when the alignment is not quite along strike, the data may leave the dip direction indeterminate. This is illustrated in Fig. 7, which shows the results of two broadside surveys over a steeply dipping geological conductor. In one survey the source was northeast of the receiver, in the other southwest of the receiver. The data on lines 1, 2, and 3, where the alignment is parallel to the conductor, indicate that the dip is to the southeast. However, the data on lines 4 to 7, southwest of the bend in the conductor, could indicate a dip in either direction.

The equipment and procedures described have been used for several years with satisfactory results. Commonly, the in-line procedure is used for reconnaissance surveys, except in very difficult terrain, or when lines are to be cut for other purposes, when the broadside procedure is used. The broadside procedure is preferred for detail surveys after conductors have been found.

Acknowledgment

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References

[1] M. Mason: Geophysical Exploration for Ores. *AIME Trans.*, 1929, vol. 81, pp. 9-36.

[2] T. Zuschlag: Mapping Oil Structures by the Sundberg Method. *AIME Trans.*, 1932, vol. 97, pp. 146-147.

[3] H. Hedstrom: Phase Measurements in Electrical Prospecting. *AIME Trans.*, 1940, vol. 138, pp. 436-471.

[4] C. A. Heiland: *Geophysical Exploration*. Prentice-Hall Inc., New York, 1940.

[5] G. ff. Bellairs: Instrumentation for a New Electromagnetic Geophysical Field Technique, as Applied in South Africa. *Geophysics*, 1955, vol. 20, pp. 155-162.

[6] J. F. Enslin: A New Electromagnetic Field Technique. *Geophysics*, 1955, vol. 20, pp. 318-334.

Utilizing and Disposing of Waterborne Industrial Wastes

Fact finding and applied research are needed to control waterborne mineral wastes and to use them economically.

by A. A. Berk

LAGGING technology and the slow spread of information have been the chief obstacles to widespread participation in minimizing the industrial pollution load. These obstacles can be conquered by fact finding and applied research.

There are three aspects to the problem of waterborne mineral waste: to minimize the amount being thrown away, to select a predisposal treatment, and to use the products or dispose of them.

It is often possible to minimize the waste by making very minor changes in the process that produces it. For example, a manufacturer of automobile bumpers greatly reduced the dragout from a plating bath by modifying the design and position of two boltholes.[1] A plater of automobile hubcaps installed a drainage bar and decreased the loss of chrome-plating solution to the rinse water by about 80 pct.[2] The mill at a western mine found it possible to discard 60 to 70 pct of an ore with minimum treatment,[3] so that the processing effort could be concentrated on a high-graded slime, with significant reduction in costs and improvement in recovery.

The possibilities for waste reduction through process changes are limited only by the imagination. A recent patent points out the advantages of using No. 1 fuel oil instead of water in wet-process cement making;[4] the fuel oil presumably has better properties than water for this purpose and is said to be almost completely recovered or utilized, so that there is no waterborne waste.

Recycling to reduce wastes and improve process economy is very well illustrated in vanadium and uranium recoveries from relatively low grade ore. Ores containing 6 pct calcium carbonate were found to give poor vanadium recovery by the salt-roasting process because the vanadium was converted to water-insoluble calcium vanadate. Following the salt-roasting process, sulfuric acid was used to leach the uranium. Enough calcium sulfate was formed

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in this step to set as a plaster of paris and interfere with percolation of the acid. Research showed that a sufficient amount of waste hydrochloric and sulfuric acids could be obtained from roaster-gas scrubbers to neutralize the calcium carbonate in the ore before it was salt-roasted. This not only proved to be a very good method of neutralizing waste acid, but also eliminated difficulties generally encountered with high-lime ores.[5] There was even an overall reduction of acid consumption in the process.

A large lime producer has found a solution to a serious disposal problem by changing a relatively simple process. Air pollution from rotary kilns was being controlled by washing the dust-laden gases. Sulfur oxides from the coal contributed to the supersaturation of the washings with calcium sulfate, and lime salts crystallized on all surfaces in contact with the wash water, including the piping. In addition, huge quantities of ash-contaminated solids were accumulated after a few months of operation. Replacing the coal with natural gas from a local source has virtually eliminated the sulfur contamination.[6] Also, the ash-free dust is relatively pure white lime and well worth recovering in a dry scrubber. Dry removal of a large part of the dust greatly reduces the load on the wet scrubber and makes it possible to stabilize the washings by using part of the carbon dioxide in the kiln gases to convert the dissolved calcium hydroxide to calcium carbonate. The clarified wash water is available for recycling.

Evaluation of Tailings: Another advantage of a process review is that the operator becomes aware of the large processing investment being thrown away in the tailings. This in itself should be an incentive to determine exactly what is wasted and in what quantity. Such surveys have led many producers of sand and gravel to extract fine sizes of sand from wash water, using Dutch wet cyclones especially adapted for this purpose.[7] Needed grades of fine sand were thus obtained more cheaply than by other methods, and waterborne wastes were significantly decreased.

The importance of finding out what is being thrown away should need no stressing. Phosphate miners in Florida developed a good-sized subsidiary industry when uranium was found in important quantities.[8] A large fertilizer industry is based on waste sulfur, recovered in gas scrubbers.[9] Zinc and lead tailings were important sources of these metals in a war economy.[10] Tailings from local washing operations have been found well suited for the raw material needed by a lightweight mineral-aggregate industry. Anthracite fines have been successfully and advantageously recovered from culm,[11] often from deposits already polluting streams and rivers.

These are just a few of the process and control changes that have resulted in less waste and improved process efficiency. Other examples could be chosen, such as the improvements in process equipment to obtain more complete separations and to decrease the quantity of undesired material sent from one unit process to another. Analytical techniques have been developed as rapid control methods for monitoring stepwise processes, and such instruments as the polarograph[12] and spectrograph are receiving special application for rapid determination of metal concentrations at various stages in mineral processing.

Acid Mine Water: There is one outstanding exception to the premise that adequate information is a prerequisite for controlling wastes or using them economically. This exception is the acid water from coal mines. The magnitude of this waste in terms of sulfuric acid pollution is huge, but individual sources contribute relatively small quantities so diluted with water that accepted technologic practices cannot be applied advantageously. Neutralization is a practical impossibility, if only because of the high alkali requirements and the resulting poor water quality. It is noteworthy that coal mine acid is exempt from the new basic treatment requirements adopted for industrial waste in the Ohio River valley.[13]

However, it is known that the acid wastes will not form unless sulfidic mineral matter is reacted with air and water.[14] Important strides have been made by sealing abandoned coal mines to prevent access of air. In Pennsylvania and West Virginia it has been demonstrated that pollution load can be controlled by diverting as much water as possible from the mines.[15] Covering up the pyritic shale and reject coal from stripping operations accomplishes the double purpose of limiting the access of both air and water.[16] It is especially encouraging to note a recent report that the industry, in particular the Indiana Coal Producers Ass'n, is actively supporting pollution control, using these methods.[17]

Several years ago it was announced that a chemical method of control had been developed at Johns Hopkins University. This research is a step in the right direction and, when the work is discussed more openly, could well lead to a practical and economical method for controlling nature's huge production of sulfuric acid.

Predisposal Treatment: Most waste disposal problems in industry will still be troublesome after they have been diminished by good housekeeping and process improvement. In the mining industry the principal waterborne wastes are the fines and tailings from ore and coal washing or from a variety of milling operations including flotation and gravity separation. Unfortunately, the small particle size that facilitates processing and makes for more complete mineral upgrading also promotes movement of the tailings into the streams.

Soluble wastes also may be troublesome. The more specialized problem of coal-mine acid is duplicated on a smaller scale in metal mining. It is not uncommon to find soluble toxic materials such as lead, copper, and zinc salts in mine waters, and many of these waters are acid. A current problem in the Ohio River valley is the rising manganese content of the water. In a class by itself is the brine removed with petroleum from oil wells, often in such quantity that its discharge to local streams would make the water brackish and unfit for industrial or domestic use.

Wastes of the mineral processing industries are more varied. Tailings from flotation mills may contain kerosene and other oils, as well as a variety of beneficiating chemicals. Other mills discharge cyanides. Wet processes contribute acids, alkalis, and a variety of salts. The manufacture of iron, steel, and other metals produces liquid wastes ranging from palm oil to strongly acidic pickling liquor. Coking and gas-making add phenols and other undesirables. Operations closely allied to the mineral industries contribute metal-bearing plating wastes, lubricating oil, and a heterogeny of suspended matter.

Many of these waste problems yield quickly to

applied technology. Others cannot be solved by any economical or practical solution now known, and there is great need for basic research on such wastes as pickle liquor and acid mine water.

Material in Suspension: The mining industry's chief problem is material in suspension, and a variety of sedimentation schemes have been devised to cope with it. Northwestern miners dammed the streams that received tailings. This practice clarified the water that flowed over the dams, but all too often a cloudburst washed everything downstream, covering arable land with silt. Research in the Coeur d'Alene area[18] showed that effective control could be established by dredging basins in the path of water to receive the periodic flows of sediment. At the other extreme, the pebble-phosphate industry in Florida has resorted to immense settling areas through which the waste water flows, often in tortuous channels, to rid it of the slimes from washing, screening, and flotation processes. Research at the University of Florida[19] has shown that this method is successful both with respect to completeness of sedimentation and re-use of the clarified water. Culm is now kept out of the Schuylkill River by a well engineered series of sedimentation channels. Relatively small flows receive adequate settling time in parallel tanks.

A settling basin, to be effective, must provide a low flow rate for the waste water and retain it long enough to permit substantially complete clarification. Also, there must be provision for bypassing the flow through a parallel unit while accumulated silt and sludge are removed. Very few basins were found to conform to these requirements when the U. S. Bureau of Mines very recently made a survey in New England,[20] and the effluents frequently were about as turbid as the untreated wastes. In many instances there simply was not enough land available for adequate sedimentation basins.

There are other methods of clarifying water. Thickeners are used where the coarser part of the load is worth recovering, and valuable slimes are often filtered. However, thickening and filtration are expensive and usually justified only by the value of the recovered solids or the need for the clarified water.

Much research has been done on accelerated sedimentation, and a variety of materials called flocculation aids are now available. Examples are Aerofloc (American Cyanamid Co.), Separan (Dow Chemical Co.), Lytron (Monsanto Chemical Co.), and Formula 600 (National Aluminate Co.). One pound of flocculation aid per hour is said to treat waste flows of 10,000 gpm[21] so that the silt burden in the water drops from 3 or 4 pct to well below the 1000 ppm permitted by some states. With tungsten slimes the capacity of existing thickeners and filters has been greatly improved by about 0.1 lb of additive per ton of dry material recovered.[22] Reports on this application indicate speedier, more complete separations and much drier products than from unaided processing. Applications have been reported in a number of coal washeries, blast furnace gas washeries, ore dressing mills, and dredge ponds. Other useful results are better separations of copper concentrates and the clarification of thickener underflows in cyanidation plants.

Although the flocculation process is not completely explained, the function of the flocculation aid appears to be to change the electrical environment around each tiny particle by attaching itself to the particle, afterward forming bridges between adjacent particles so that coagulation and rapid sedimentation take place. Some promotional literature has claimed that settling rates are increased more than 40 times. Where the suspended matter in waste water is worth recovering, flocculation aids are well worth the research necessary to determine application rates for required effectiveness and costs in relation to recoverable values. This research has a practical side, since it is not economical to feed an expensive chemical in large amounts to increase the rate of settling 20 times when a slower rate of settling, obtainable with less chemical, will fit better into the flow diagram of the process.

Despite these advances, there is great need for basic research toward less expensive flocculation. One company estimated that it would cost $40 per day to halve the retention time necessary to achieve a 90 pct reduction in suspended solids, initially 2000 ppm, in blast furnace gas wash water entering the launder at the rate of about 10,000 gpm. This cost would be offset by the recovery of about 80 tons of flue dust per day and therefore was not unreasonable. A similar charge against a sand and gravel washery, where the only utilization of the suspended matter might be land fill, would not be very attractive.

Although flocculation aids offer the most promising field for basic research in sedimentation, processes involving chemical coagulation reactions or agglomeration through sonic phenomena might well have superior application to special problems. Mechanical devices for increasing gravitational effects, such as the wet cyclone, also have special fields of usefulness, especially when one species or size in the sediment must be separated from the remainder.

Materials in Solution: Research on the steel industry's pickle-liquor problem is once again active. Some of the larger steel companies are currently making a pilot plant study[23] of an Austrian process that uses hydrochloric acid gas to remove the contaminating iron from the liquor so that the sulfuric acid is regenerated and may be recycled. In England a pilot plant study[24] is being made of an evaporation process that removes the iron as the sulfate monohydrate, which is then decomposed to sulfur dioxide as a step toward recovering the sulfuric acid. This activity could well be supplemented by additional vigorous research on methods of conserving the sulfuric acid and on integration of this conservation with steel processing.

Much research has been done on removing valuable metals from wastes by chemical processes and by ion exchange methods. Ion exchange has been made especially attractive for concentrating and recovering salts of copper, nickel, and chromium.[25,26] Additional research, especially designed to help the small plater, should be directed toward developing continuous ion exchange processes.[27] These would lessen the need for storage tanks and would therefore be especially attractive to operators with space problems, thus decreasing the aggregate pollution from plating wastes and effecting valuable recoveries of important metals.

Other soluble wastes, such as phenols and cyanides, are receiving much current attention in research laboratories. Phenol recovery is being practiced on an increasing scale by coke plants, and the petroleum industry has shown that residual phenol can be substantially removed by controlled bacterial action.[28] Cyanide studies have shown that con-

trol can be effected by careful aeration or by oxidation with chlorine or ozone. It is noteworthy, however, that at least one processor is recovering cyanide by multiple-effect evaporation[29] from a dilute waste that is sent to the still at the rate of 100 gal per hr. The fact that this plant recovers the cyanide for 18¢ per lb when it would cost 60¢ per lb to destroy it with chlorine emphasizes the need for careful research and appraisal before a predisposal treatment is adopted.

Other soluble waterborne wastes are important in the mineral industry. In some instances available dilution is sufficient for a practical solution. For example, consumers downstream from a graphite mine complained about the taste of the pine oil used to float the graphite. The major research involved developing a method for determining pine oil in water.[30] By using this method it was shown that obnoxious concentrations of pine oil were found in the stream only occasionally. Impounding the waste water behind a dam equalized the concentration to a very small and nearly undetected level.

There is now a developed technology from which answers may be obtained for many of the predisposal treatment problems of the mineral industry. It is not always clear to the plant or mine operator where to look for this information. It might be well to remember that most Federal agencies have specialists who are ready to draw on the accumulated technical knowledge of their agencies to supply the correct answer and that the USBM is especially equipped to serve the mineral industry.

Disposal of Wastes: The ultimate disposal of the mineral wastes, both treated and untreated, depends a great deal on local conditions and local restrictions. Convenient streams and sewers can be utilized when the waste waters have been sufficiently decontaminated. A du Pont plant in Texas follows the practice of deep-well injection of brines and other chemicals.[31] This reinjection method was originally developed and applied successfully to oil-field brines by the USBM.[32] The judicious surface and subsurface disposal of liquid wastes may be an important method of controlling watershed pollution in areas where geologic and engineering factors permit such disposal.

Frequently the waste water has a quality that is superior for the plant processes to that of raw water. This may arise from removal of hardness or some other undesirable component from the water during its progress through the plant, or it may have picked up a significant content of chemicals that it would be advantageous to recycle. In some instances the waste water is warm, and its heat content is worth saving. Where water is scarce, as at the Kaiser Steel Co. at Fontana, waste water is re-used through necessity, and the refuse from one system becomes the supply for the next.[33] The research required for reclaiming even grossly contaminated process waters has in many instances been repaid by water savings, independence from a variable water supply, and greater plant efficiency.

Often most of the waste water could be re-used if it were not contaminated by a relatively small volume of concentrated waste. This situation may arise from the periodic discharge of pickling baths or plating solutions. In such instances segregation can usually be practiced profitably, both with respect to predisposal treatment and ultimate discharge. The slow bleeding of concentrated wastes into the plant's sewer may result in enough dilution to meet local requirements. If so, the cost of a retaining tank will generally be much less than that of a treatment plant. In any instance, it is axiomatic that batch disposal creates the severest possible shock on any living organism in the stream and that equalization is the preferred technologic practice.

Sediment removed from mineral wastes usually becomes land fill or stope fill in mines. However, the sediment is occasionally too valuable for this purpose and is returned for further processing. For example, the Bethlehem Steel Co. at Bethlehem installed a treatment plant to remove blast furnace flue dust from wash water. This operation not only produced an acceptably clean effluent, but so much ore is being recovered that the plant showed a profit of more than half a million dollars in its first year.[34] Although sediment does not often have a value of $9.51 per ton, it is good business to look for values in what is being thrown away.

References

[1] C. F. Gurnham: *Principles of Industrial Waste Treatment*, p. 101. John Wiley & Sons Inc., New York, 1955.

[2] *Plating Room Controls for Pollution Abatement*. Ohio River Valley Sanitation Commission, 1951.

[3] The Climax Molybdenum Section. MINING ENGINEERING, vol. 7, 1955, p. 766.

[4] J. C. Witt: Wet Process for Portland Cement Manufacture. U. S. Patent 2,611,714, Sept. 23, 1952.

[5] Ref. 3, pp. 766-767.

[6] Communication from the Warner Co., Bethlehem, Pa.

[7] Recovering Fine Sand with Scalper Cyclones. *Rock Products*, vol. 58, August 1955, pp. 66, 67, 190.

[8] Recovering Uranium as a Byproduct in Phosphate Plants. *Rock Products*, vol. 58, October 1955, pp. 96, 98, 100, 102.

[9] R. S. Dean: Fixation of Sulfur from Smelter Smoke. *USBM R.I. 3339*, 1937, 51 pp.

[10] A. J. Martin: Summarized Statistics of Production of Lead and Zinc in Tri-State (Missouri-Kansas-Oklahoma) Mining District. *USBM Inf. Circ. 7383*, 1946, Graph No. 4.

[11] P. Levin and J. P. Ledvina: Recover River Coal for Power Generation. *Mining Congress Journal*, vol. 40, November 1954, pp. 52-57.

[12] Use of Polarograph in Process Control. *Engineering and Mining*, vol. 156, September 1955, pp. 97-99.

[13] Seventh Annual Report: Ohio River Valley Water Sanitation Commission, 1955, p. 11.

[14] R. D. Leitch and W. P. Yant: Comparison of Acidity of Waters from Some Active and Abandoned Coal Mines. *USBM R.I. 2895*, 1928, 8 pp.

[15] Acid Mine Drainage Studies, Supplement *C* to Final Report to the Ohio River Committee: U. S. Public Health Service, 1942.

[16] S. A. Braley: Acid Mine Drainage—VII. Strip Mines. *Mechanization*, vol. 18, August 1954, pp. 101-103.

[17] B. A. Poole and Holtje: Progress of Stream Pollution Control in Indiana. *Journal of American Waterworks Association*, vol. 46, 1954, p. 672.

[18] W. L. Ziegler: Tailings Disposal in the Coeur d'Alene River. *Proceedings*, 14th Annual Convention of the Idaho Mining Association, 1935, pp. 54-59.

[19] R. C. Specht: Phosphate Waste Studies. Florida Engineering and Experiment Station *Bull. 32*, 1950, 26 pp.

[20] B. P. Martinez: Waterborne Wastes of the Mineral Industries New England-New York Region. *USBM R.I. 5289*, 1956, 42 pp.

[21] J. K. Rice: Use of Coagulant Aids. *Proceedings*, 16th Annual Water Conference, Engineers Society of Western Pennsylvania, 1955, pp. 83-88.

[22] D. J. Pye: How Synthetic Flocculants Help the Mill Operator. *Engineering and Mining Journal*, vol. 156, November 1955, pp. 94-96.

[23] T. F. Barnhart: Evaluation of a Waste Pickle Liquor Treatment. *Iron and Steel Engineer*, vol. 32, December 1955, pp. 62-65.

[24] W. Bullough: Closed Cycle Sulfuric Acid Pickling System (With Acid Recovery from Waste Pickle Liquor). *Sheet Metal Industries*, vol. 33, 1956, pp. 243-246.

[25] R. J. Keating and J. H. Duff: Plating Waste Solutions—Recovery or Disposal. *Proceedings*, 10th Annual Industrial Waste Conference, Purdue University, 1955, pp. 61-73.

[26] K. Odlund and J. C. Hesler: Profitable Recovery of Plating Wastes. *Plating*, vol. 43, 1956, pp. 1022-1025.

[27] W. A. Selke and H. Bliss: Continuous Countercurrent Ion Exchange. *Chemical Engineering Progress*, vol. 47, 1951, pp. 529-532.

[28] A. V. Delaporte: Industrial Waste Treatment in Ontario. *Proceedings*, 9th Industrial Waste Conference, Purdue University, 1954, pp. 352-359.

[29] L. Weisberg and E. J. Quinlan: Cyanide and Chromium Recovery from Plating Wastes. *Sewage and Industrial Wastes*, vol. 28, 1956, pp. 998-1008.

[30] J. A. Sutton: A Colorimetric Method for Determining Pine Oil in Water. *USBM R.I. 4990*, 1953, 15 pp.

[31] H. O. Henkel: Subsurface Disposal of Chemical Wastes. *Chemical Engineering Progress*, vol. 51, 1955, pp. 551-554.

[32] P. Grandone and L. Schmidt: Survey of Subsurface Brine-Disposal Systems in Western Kansas Oil Fields. *USBM R.I. 3710*, 1943, 20 pp.

[33] H. I. Riegel: Waste Disposal at the Fontana Steel Plant. *Sewage and Industrial Wastes*, vol. 24, 1952, pp. 1121-1129.

[34] R. M. Heister: Industrial Waste Treatment in Pennsylvania. *Sewage and Industrial Wastes*, vol. 28, 1956, pp. 660-665.

Synthesis of Some Ferrites

by Horst Kedesdy and Arthur Tauber

FERRITES are sintered metallic oxides of the spinel structure type[1] and belong to the class of soft ferromagnetic materials. Similar to a ceramic, they can be formed and fired to a dense body, exhibiting a high electrical volume resistivity ranging from 10^2 to 10^7 ohm-cm as compared with 10^{-6} ohm-cm for some of the metallic magnetic materials. This high resistivity, with resulting low eddy current losses, finds special application at high frequencies. The dispersive susceptibility of ferrites at microwave frequencies has also led to many applications in this field. Where high resistivity with high permeability is desirable, ferrites are used in low frequency applications. During the last few years ferrites exhibiting rectangular hysteresis loops have been developed for computer and magnetic memory systems.

The general formula for ferrites is $MeFe_2O_4$ where Me is a divalent metal ion such as Ni, Zn, Mg, Mn, Cu, Cd, and Fe. Only two of these ferrites are nonferromagnetic, namely, those with Zn and Cd. Solid solutions can be formed between different ferrites, and it is of interest to note that solid solutions of a ferromagnetic ferrite with a nonferromagnetic ferrite yield much better magnetic materials than the basic ferrite body. In general, it can be said that the solid solution formation between ferrites has widened the field of ferrite synthesis and has led to methods of preparing materials with a large variety of magnetic properties.

During the last two decades the synthesis of ferromagnetic oxides has been the object of extensive research, but commercial production has been started only within the last ten years. Along with more fundamental studies, there remains the never-ending task of developing ways to realize the optimum characteristics of materials in large-scale production. Ordinarily, to produce a ferrite material it is necessary for the constituent oxides to be mixed intimately, pressed, and then fired at temperatures above 1000°C.

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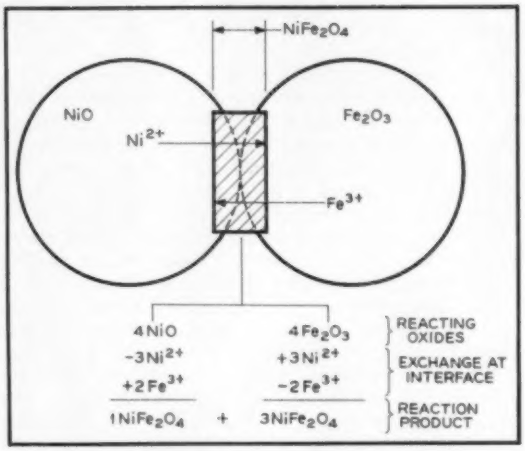


Fig. 1—Reaction mechanism for Ni-ferrite formation. (After C. Wagner.[5])

Ferrite Synthesis: Formation of a basic ferrite by solid state reaction from Fe_2O_3 and a monoxide such as NiO, under normal atmospheric conditions, is governed by a progressive diffusion of cations between adjacent particles of the constituents. Firing temperature, furnace atmosphere, and cooling can vary the magnetic properties, however. If, for example, a dioxide, a sesquioxide, or an oxide of the MeO type is substituted for the monoxide, the reaction mechanism becomes more complex and extremely dependent on atmospheric conditions and firing cycles. For this reason reproduction often

Table I. Spectrochemical Analysis of the Constituent Oxides and Fired Toroid Cores*

Element Analyzed for	Fe_2O_3	$MnCO_3$	NiO	$NiFe_2O_4$	$Ni_{.5}Zn_{.5}Fe_2O_4$	$MnFe_2O_4$
Si	0.01	<0.01	0.08	0.1	0.1	0.01
Al	0.01	0.01	0.005	0.02	0.002	<0.01
Fe	Major	<0.01	Not detected	Major	Major	Major
Mg	Not detected	0.01	Not detected	Not detected	Not detected	<0.01
Ca	Not detected	<0.01	Not detected	Not detected	Not detected	0.01
Pb	Not detected	<0.02	Not detected	Not detected	Not detected	Not detected
Sn	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
Ti	<0.01	Not detected	Not detected	Not detected	Not detected	0.01
V	<0.01	Not detected	Not detected	Not detected	Not detected	Not detected
Cr	<0.01	Not detected	<0.001	Not detected	Not detected	Not detected
Mn	0.01	Major	0.01	<0.01	<0.01	Major
Cu	<0.01	Not detected	0.002	0.003	0.003	<0.01
Ni	0.01	Not detected	Major	Major	Major	0.01
Zn	Not detected	Not detected	Not detected	Major	Major	Not detected

* Results are in weight percent.

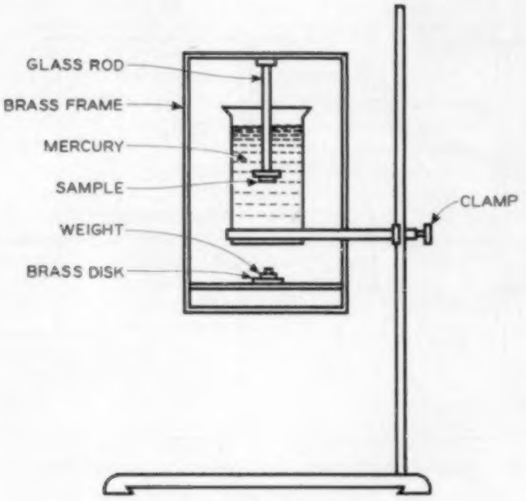


Fig. 2—Bulk density apparatus.

fails even in cores from the same batch material, with the same magnetic properties. Synthesis of a ferromagnetic oxide of final magnetic properties consists not only of a completion of the solid state reaction between the constituent oxides to form the spinel structure, but also in the densification of material, diffusion of the cations to form a homogeneous body, and grain growth.

This article discusses results of systematic investigations of the formation of a basic ferrite, such as Ni ferrite; a mixed ferrite, such as NiZn-ferrite; and a ferrite involving a complex formation process, such as Mn-ferrite. Trends in magnetic characteristics are related to change in firing cycle and furnace atmosphere.

Specimen Preparation and Testing Procedures: For synthesis of Ni- and NiZn-ferrite, constituent oxide mixtures consisted of Fe_2O_3 with NiO and with NiO + ZnO (1:1); for the Mn-ferrite synthesis an oxide mixture of Fe_2O_3 and Mn_3O_4 was chosen.

Single-phase Baker-analyzed reagent NiO, Fisher ZnO, and Fe_2O_3 of C.P. grade were used in preparing the samples. Mn_3O_4 was prepared from Fisher C.P. grade Mn_3O_4 by heating in air at 1000°C for 1 hr and air quenching to room temperature. The sample was then reground, reheated for another hour at the same temperature, and then quenched to room temperature. Particle size, as determined by electron microscopy, was about 0.01μ for Fe_2O_3, 0.1μ for NiO, and 1μ for Mn_3O_4.

Pellets ½-in. OD and 4 in. thick, pressed at 25,000 psi, were used for the solid state reaction studies. The pellets were prepared from the powdered oxides, which were dried overnight at 110°C. The exact weights of oxides were measured, mixed, and ground in the dry state in a boron carbide mortar for about 3 hr. Spectrochemical analysis indicated no contamination from the mortar.

For the magnetic studies toroids were selected, prepared by mixing and grinding carefully weighed constituent oxides. The dry oxides were ground in a boron carbide mortar in 3 hr. Subsequently each mixture was pressed into pellets at 25,000 psi, calcined in static air at 950°C for 5 hr in a globar furnace, and cooled by air quenching. The calcined

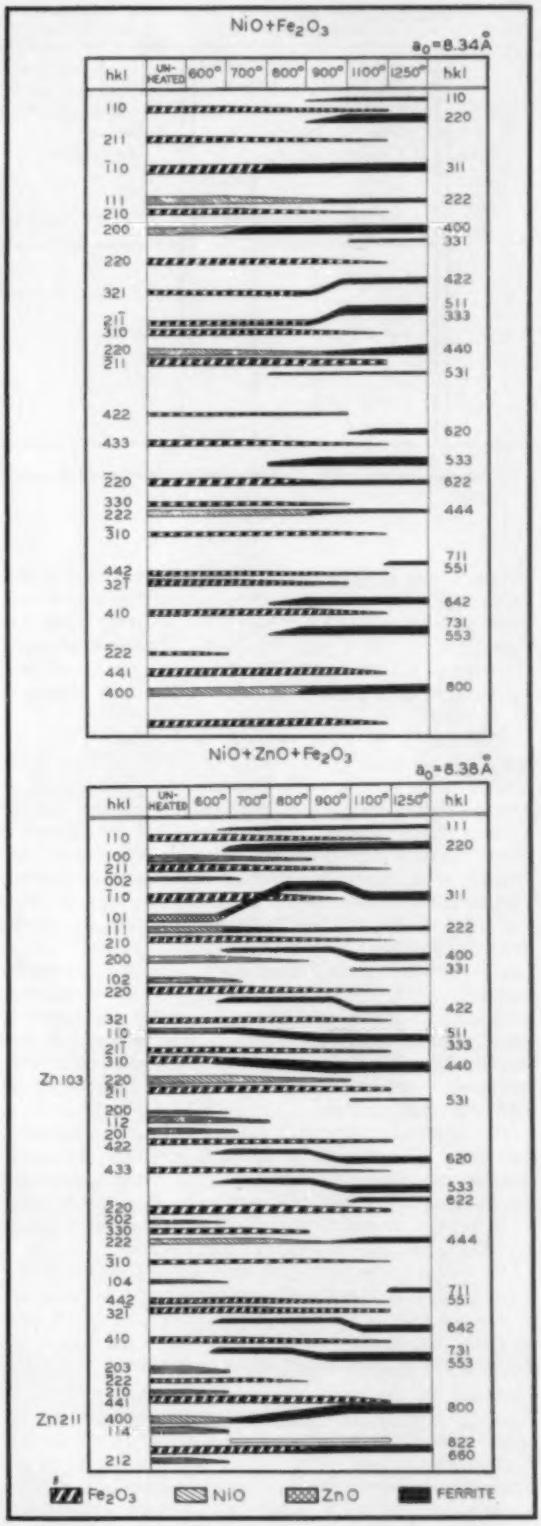


Fig. 3—Ferrite formation from X-ray diffraction data.

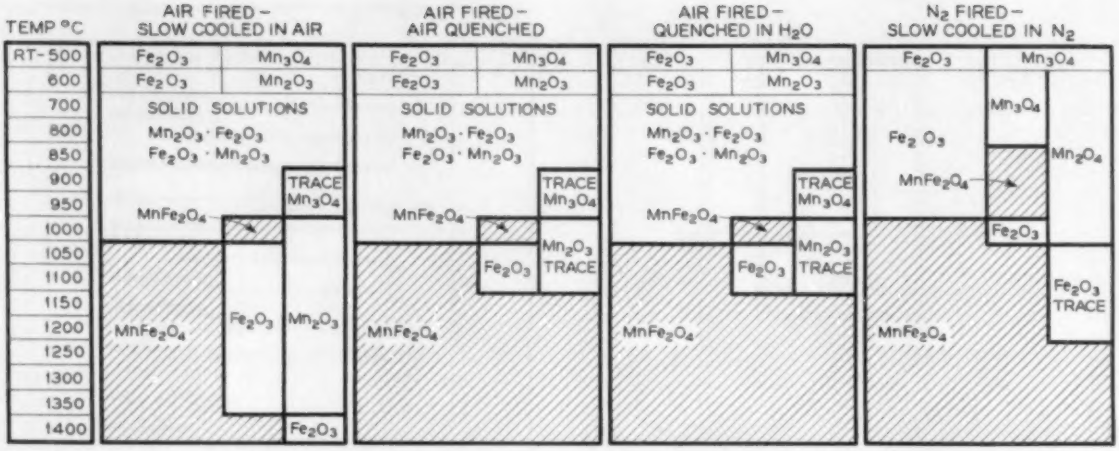


Fig. 4—The Mn-ferrite formation under different firing conditions. Wide columns indicate major phase and narrow columns minor phase.

product was broken up in a steel mortar and transferred to a motorized mullite mortar, where it was ground with water for 2 hr. The resulting cake was dried out at 110°C and the material passed through a series of sieves; the last increment contained particles that had passed through a No. 150 Standard U. S. sieve.

For every 50 g of sample, 2 cu cm of a 4 pct aqueous solution of DuPont Polyvinyl alcohol were added as a binder. The binder was volatilized as the toroids were heated slowly during the appropriate firing cycle. Spectrochemical analyses of these toroids are given in Table I. All pellets and toroids were fired in a Baker E-2 platinum wound resistance furnace. Both pellets and toroids were fired for 5 hr, at the final temperature, with the following firing cycles:

A. Heated and Slow-Cooled in Air: Samples heated in this cycle were brought to the final temperature at about 150°C per hr. After the samples were soaked 5 hr, the furnace was turned off and the cooling followed a parabolic curve; room temperature was reached in 2 to 3 hr, depending on the soak temperature.

B. Heated in Air and Quenched in Air: The heating cycle was the same as in *A*. Cooling, however, was accomplished by removing the sample from the furnace at its soak temperature, then permitting it to cool to room temperature on a ceramic block; cooling time was no longer than 10 min.

C. Heated in Nitrogen and Slow-Cooled in Nitrogen: The heating cycle was the same as in *A* and *B* except that a nitrogen atmosphere, at a pressure slightly above atmospheric and at a flow rate of 0.5 liters per min, was maintained throughout the entire firing cycle. After 5 hr of firing the furnace was turned off and the sample left to cool. Here, a nitrogen stream was maintained until room temperature was reached to speed the cooling process in this part of the cycle.

D. Heated in Air and Quenched in Water: This additional firing cycle, used in the study of Mn-ferrite, applies to formation studies only. The heating cycle was identical to the cycle for samples fired previously. The sample was then removed quickly from the furnace while it was at soak temperature and dropped into distilled water, cooling to room temperature within 8 sec. Firing temperatures ranged from 600° to 1400°C for the solid state reactions and from 1000° to 1450°C for the magnetic studies.

X-Ray Diffraction Studies: X-ray diffraction was used to study the solid state reaction. FeKα-radiation, filtered through manganese oxide, was used throughout. Both Debye-Scherrer powder film patterns and diffractometer traces were prepared. The film patterns were made by grinding to a powder the sintered ceramic material from the central portions of pellets or toroids. Diffractometer traces were prepared from powdered samples, as well as from unmodified and polished surfaces of the sintered ceramics.

Magnetic Measurements: The hysteresis loop traces were obtained with an automatic recording flux meter,[8] which produced a trace of the curves on standard rectangular coordinate paper.

All toroids were wound with 3000 primary and 30 secondary windings. The primary winding is used to generate the magnetizing force by energizing it with a controlled direct current; *H*, the

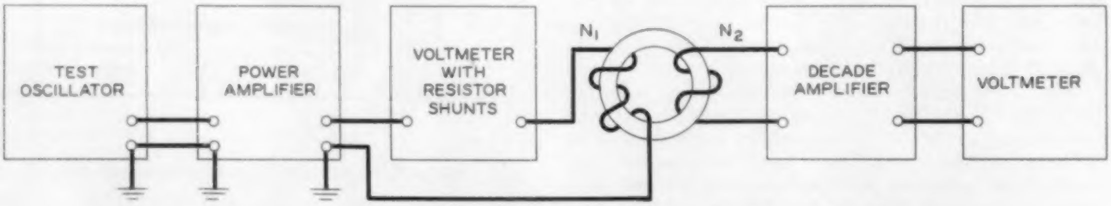


Fig. 5—Schematic block diagram for determination of initial permeability of toroidal ferrite cores.

magnetic strength in oersted, is proportional to I, the magnetizing current. The secondary winding is connected with the integrating elements of the flux meter. The meter converts the change in flux, linking the search coil, to variations in current proportional to the flux density, B. The scales of the two mechanisms of the recorder are adjusted by the two currents fed to it through separate networks. The B element mechanism drives the pen proportionately to B, while the H mechanism drives the paper drum proportionately to H. The B-H loop is traced by constantly increasing the magnetic current from zero to a positive value, immediately followed by a cyclic reversal of the same value. All measurements were made at a maximum field strength (H) of 25 oersteds. Initial permeability (μ_i) was determined with a conventional bridge circuit at 1 kc. Measurements for initial d-c permeability were made on the same toroids used for hysteresis loop tracing without a change of windings. An oscillator was used to drive the primary of the toroids (Fig. 3). The primary magnetizing current and voltage and the voltage in the secondary winding were measured with vacuum tube voltmeters. An average value for initial permeability was obtained for each core from nine individual measurements made close to zero field H (0-25 milli oersteds). Initial permeability can be calculated from

$$\mu_i = \frac{B}{H}$$

where

$$B = \frac{22.5 \cdot E_2}{A \cdot N_2 \cdot f}$$

$$H = \frac{0.4 \cdot \sqrt{2}\, I_1 \cdot N_1}{d_m}$$

E_2 = voltage in millivolts across secondary winding.
A = cross sectional area of core in cm^2.
N_1 = number of primary turns.
N_2 = number of secondary turns.
f = operating frequency (1 kc).
I_1 = primary current in amperes.
d_m = mean diameter of core in centimeter.

Bulk Density Measurements: Bulk density measurements were made with a device based on Archimedes' principle—a brass wire frame of about 4 x 6 in. shown in Fig. 2. A small nut is soldered in the center of the crosspiece and into this is screwed a glass rod 2 in. long that terminates in a flattened disk. Soldered to the crosspiece on the bottom of the device is a brass disk that holds the weights used in the measuring process. The whole device is suspended over a small beaker of mercury. The sample is floated on the surface and the disk of the rod rests directly on it. The weights are placed on the brass disk until the mercury meniscus is aligned with a predetermined zero point on the glass rod. The density of the sample is given by

$$d_s = d_{Hg} \cdot \frac{W_s}{W_s + W_s^1}$$

where

d_{Hg} = density of mercury in g per cm^3.
W_s = weight of sample in air, g.
W_s^1 = weight of sample in mercury, g.

Data for densities and weights must be determined at the same temperature. In these investigations measurements were performed at 26°C.

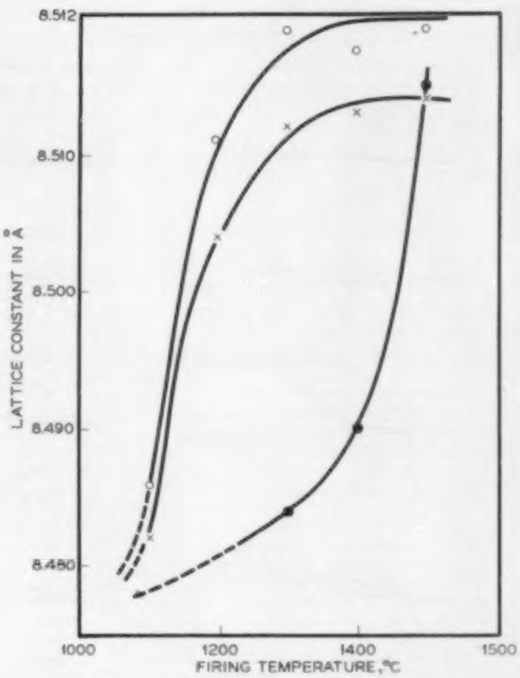


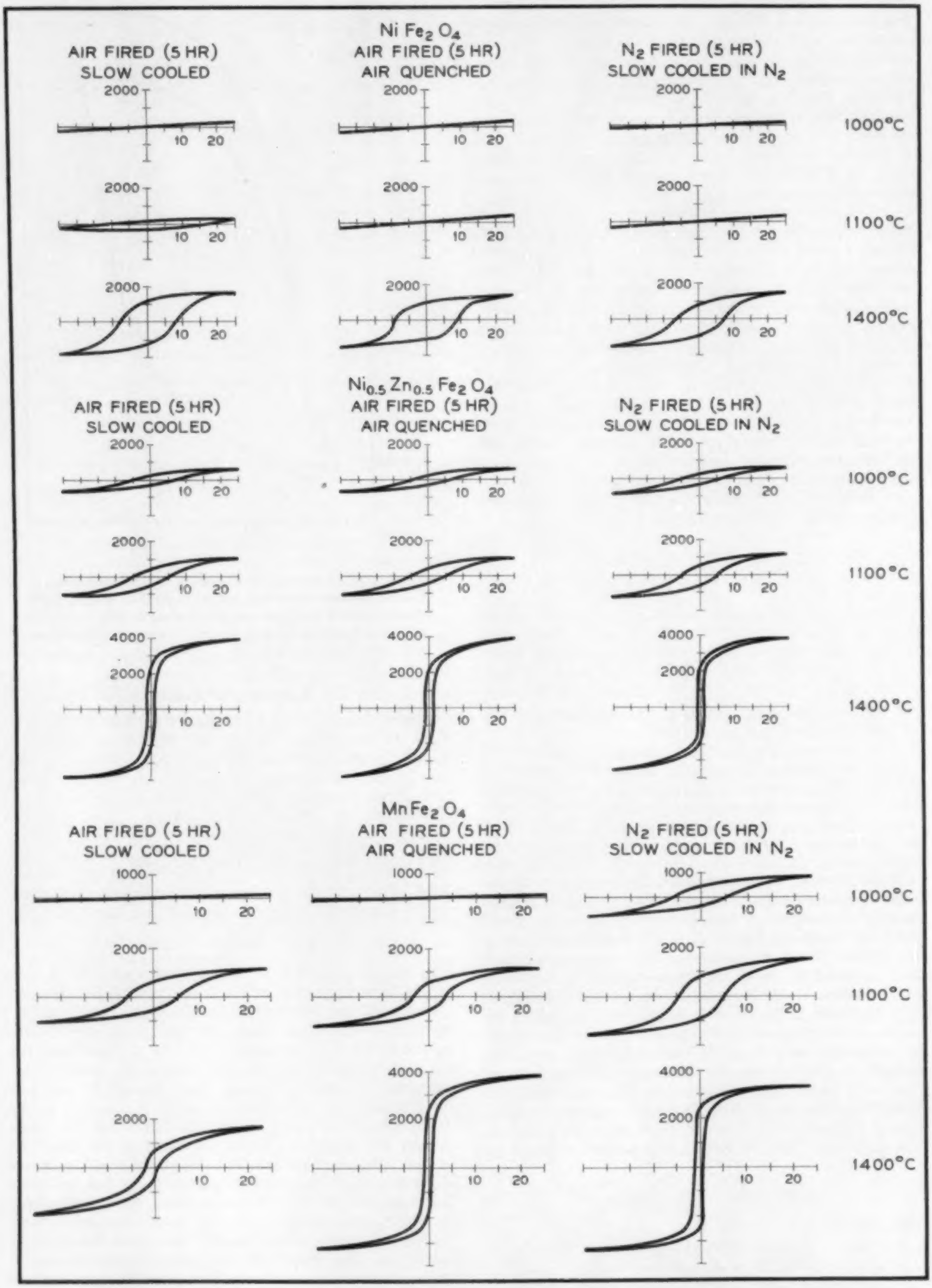
Fig. 6—Lattice constant of Mn-ferrite vs firing temperature. Crosses indicate air firing and air quenching to RT; solid circles indicate air firing and slow cooling in furnace to RT; and open circles indicate firing in a gaseous N_2 atmosphere with slow cooling in N_2 to RT.

Experimental Results

Formation of Solid State Reaction: Ferrite formation, as determined by X-ray diffraction measurements, begins between 650° and 700°C for both Ni-ferrite and NiZn-ferrite; for the Mn-ferrite, temperatures between 850° and 1000°C are required, depending on furnace atmosphere. The reaction mechanism for the formation of Ni- or NiZn-ferrites from their constituent oxides can be visualized as a Wagner type of diffusion[9] at the particle interface (Fig. 1). The reaction leading to the formation of Ni-ferrite can be represented, for example, by:

$$NiO + Fe_2O_3 \rightarrow NiFe_2O_4.$$

Fig. 3 is a graphical representation based on X-ray diffraction data, obtained from powdered ceramic pellets, of the formation in air of Ni- and NiZn-ferrite. Diffraction lines of the unreacted oxide mixture are plotted on the left side of each diagram in such a way that from the top to the bottom the diffraction angle increases. Any change in position or intensity of diffraction lines, at increasing firing temperature, is easily noted by following the lines across the diagram. The right hand of the diagram shows the completed ferrite diffraction pattern (black lines). Pronounced shifts of the ferrite lines are seen in the first stage of formation, indicating crystal lattice distortion of the newly formed ferrite phase. This distortion vanishes as higher firing temperatures are reached. Accurate lattice constant measurements have shown that for bodies quenched from 1000° to 1200°C there is first an increase in lattice constant, followed by a slight decrease. The total change never exceeds 0.005A. A single-phase material is observed after firing at 1250° or higher.



Figs. 7, 8, and 9—Hysteresis loops of Ni, Ni-Zn, and Mn ferrites prepared under different conditions. Abscissa scale is in oersteds and ordinate scale in gauss.

Table II. Chemical Reactions Governing the Formation of $MnFe_2O_4$ from $Mn_3O_4 + Fe_2O_3$ (1:3 Mols) in Air and Nitrogen

Heating in Air Atmosphere		
1. Initial mixture:		($Mn_3O_4 + 3\ Fe_2O_3$)
2. At 600°C (oxidation of Mn_3O_4):	$Mn_3O_4 + \frac{1}{4}O_2 \rightarrow 1.5\ Mn_2O_3$	($1.5\ Mn_2O_3 + 3\ Fe_2O_3$)
2. At 950°C (reduction of Mn_2O_3):	$1.5\ Mn_2O_3 \rightarrow Mn_3O_4 + \frac{1}{4}O_2$	($Mn_3O_4 + 3\ Fe_2O_3$)
4. At 1000°C (ferrite formation and reduction):	$Mn_3O_4 + 3\ Fe_2O_3 \rightarrow 3\ MnFe_2O_4 + \frac{1}{2}O_2$	($3\ MnFe_2O_4$)
Heating in Nitrogen Atmosphere		
1. Initial mixture:		($Mn_3O_4 + 3\ Fe_2O_3$)
2. At 850°C (ferrite formation and reduction):	$Mn_3O_4 + 3\ Fe_2O_3 \rightarrow 3\ MnFe_2O_4 + \frac{1}{2}O_2$	($3\ MnFe_2O_4$)

Formation of Mn-ferrite,[5] from mixtures of Mn_3O_4 and Fe_2O_3 fired in air, is not a simple reaction. The various phases detected are given in Table II. Reactions that occurred in air are compared with those that occurred in a nitrogen atmosphere. In the nitrogen-fired samples, the constituent oxides are present and unchanged up to the reaction temperature 850°C; the Mn_3O_4 in the air-fired samples undergoes an oxidation to Mn_2O_3 at about 600°C. Before Mn_2O_3 reverts to Mn_3O_4 at higher temperatures (950°C), solid solutions between Fe_2O_3 and Mn_2O_3 are observed. These solid solutions begin to dissociate (below 950°C) into Mn_3O_4 and Fe_2O_3, that is, back to the initial constituent mixture, by a reduction of the Mn_2O_3 part of the solid solution. The dissociated phases Mn_3O_4 and Fe_2O_3 probably still contain small amounts of Fe-ions and Mn-ions respectively. At 1000°C the ferrite formation from Mn_3O_4 and Fe_2O_3 can be represented by:

$$Mn_3O_4 + 3F_2O_3 \rightarrow 3MnFe_2O_4 + \tfrac{1}{2}\ O_2$$

These results, obtained from X-ray diffraction data for both air firing and nitrogen firing, are shown schematically in Fig. 4. The column to the left of each firing cycle represents the major phase at different firing temperatures; columns to the right indicate the minor phases. For the air-fired samples, ferrite formation starts at 1000°C; the nitrogen-fired samples show the first ferrite formation at 850°C. In the air-fired and air-quenched cycle, the presence of a single ferrite phase indicated that the reaction was completed at 1150°C; for the nitrogen-fired sample it was completed at 1250°C. No single ferrite phase material could be obtained when the samples were slow-cooled in air. This was determined by examining the central portion of the ceramic pellet, using X-ray diffraction.

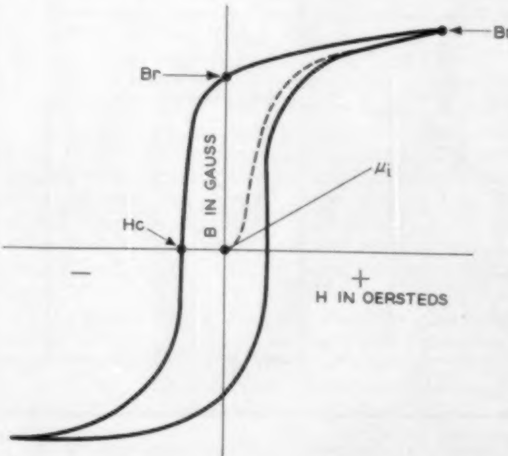


Fig. 10—The d-c hysteresis loop.

During formation of the Mn-ferrite phase, a change of lattice constant is observed which is much more pronounced than it is in the Ni- and NiZn-ferrites. With the exception of the air-fired and slow-cooled sample, the lattice constant is stabilized at about 1400°C, Fig. 6.

Magnetic Hysteresis Loop: The manner in which the magnetization B (in gauss) varies with the applied magnetic field H (in oersteds) for a typical temporary magnetic ferrite sample is shown in Fig. 10. The magnetization curve shown by the dotted line is obtained by subjecting the magnetic material that has not been magnetized before to a gradually increasing magnetizing force H. The magnetization first increases slowly and then more rapidly, and finally approaches a saturation value, B_m. For the initial part at low fields H the slope of the curve has been designated as the initial permeability μ_i, frequently employed as a figure of merit when different magnetic materials are compared. The higher the initial permeability is, the greater the likelihood that saturation will be reached at lower fields, H.

If the magnetizing force, H, is gradually reduced from the highest applied value to zero, the magnetization in the material decreases to a value B_r, known as the residual induction. If the magnetizing force is then reversed (by reversing the current in the primary winding) and increased in the negative direction, the magnetization is reduced to zero. At this point, the value of the demagnetizing force is $-Hc$, known as the coercive force. If the field H is varied cyclically between $+H$ and $-H$, a complete hysteresis curve is traced out with no return to the starting point.

Development of Hysteresis Loops: The B-H loops in Figs. 7-9 show the development of the magnetic properties of the three ferrites, as the firing temperature increases during the three firing cycles.

1. *Ni-Ferrite (Fig. 7):* It is apparent from the hysteresis loops that the three different firing methods applied cause no appreciable difference in the magnetic characteristics. From X-ray diffraction data it was established that the ferrite phase was the major phase present in the reaction product at 1100°C. Since at this firing temperature the crystallite size is small and the body is porous with a distorted lattice, the hysteresis loop is poorly developed. Ordering of the cations, sintering, and recrystallization take place at about 1250°C, where the diffraction line pattern of the ferrite is found to be sharp and is that of a nondistorted cubic lattice. At this temperature development of a characteristic hysteresis loop was also observed. Maximum flux density of the basic Ni-ferrite at a firing temperature at 1400°C is less than 2000 gauss for all three firing conditions; the coercive force is very high, ranging between 7 and 10.

2. *NiZn-Ferrite (Fig. 8):* At a firing temperature of 1000°C the hysteresis loop is more defined than in the case of Ni-ferrite. This is in agreement with the reaction studies, where it was observed that the beginning of the NiZn-ferrite formation took place at a somewhat lower temperature. The greatest improvement in development of the hysteresis loop can be seen in the sample fired at 1400°C. The maximum flux density appears to be twice as large and

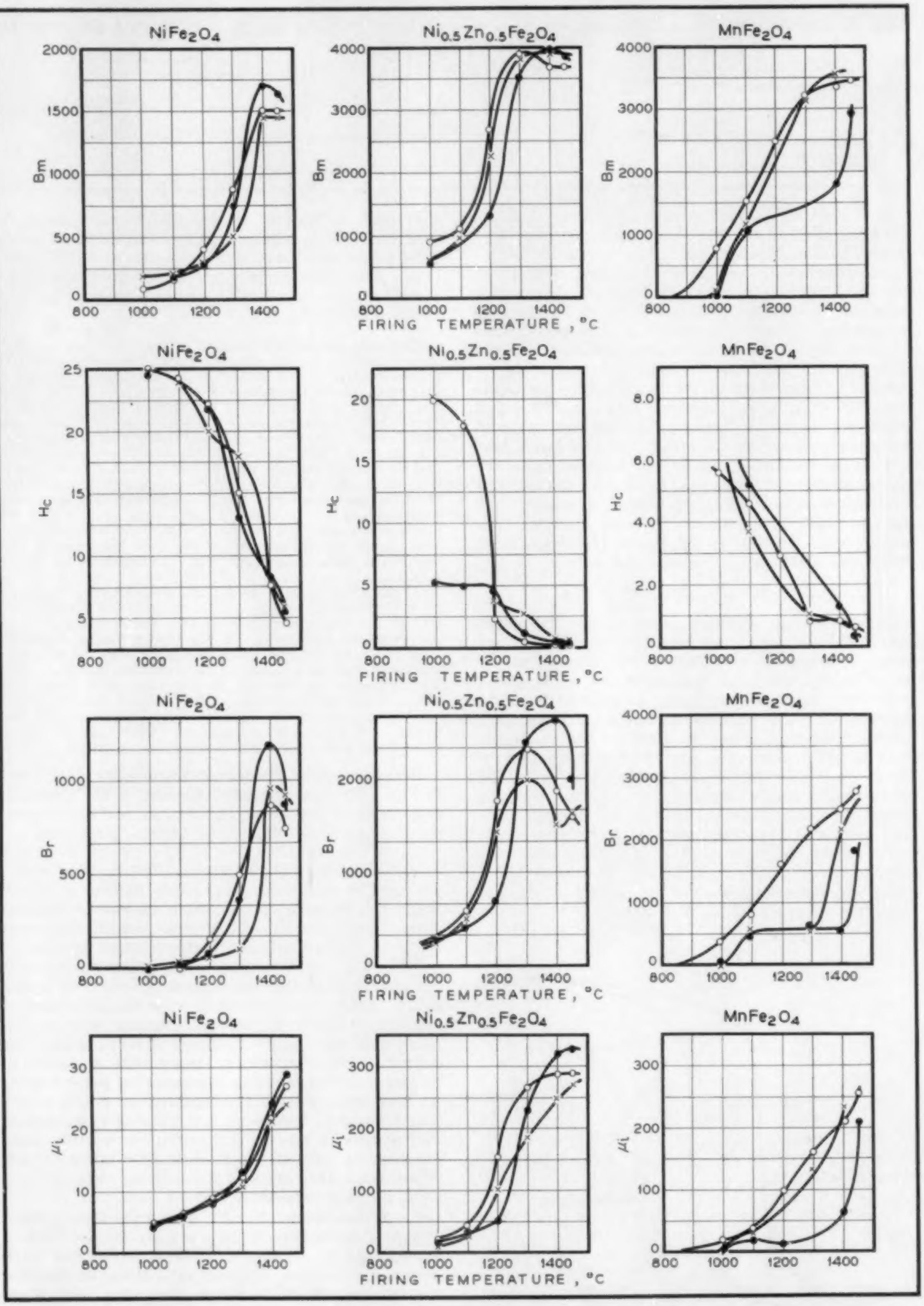


Fig. 11 (top row)—Maximum flux density vs firing temperature. Fig. 12 (second row)—Coercive force vs firing temperature. Fig. 13 (third row)—Residual induction vs firing temperature. Fig. 14 (last row)—Initial permeability vs firing temperature. In each instance crosses indicate air firing with air quenching to RT; solid circles indicate air firing and slow cooling in furnace to RT; and open circles indicate firing in a gaseous N_2 atmosphere with slow cooling in N_2 to RT.

Table III. Comparison of Magnetic Data of Ni-, NiZn, and Mn-Ferrite Prepared Under the Most Favorable Conditions Between 1200° and 1450°C

Ferrite	Firing Temp, °C	Bm Gauss	B_r Gauss	$K = \frac{B_r}{B_m}$	H_c Oersted	μ_i (at 1 KC) 1	Firing Cycle
Ni—	1200	300	80	0.27	22	8.5	Air fired—slow cooled
	1300	750	375	0.50	13.2	13.0	
	1400	1700	1200	0.71	8.2	24.2	
	1450	1630	875	0.54	5.4	29.5	
Ni, Zn— (1:1)	1200	1350	700	0.52	4.6	54.4	Air fired—slow cooled
	1300	3550	2150	0.61	1.2	231	
	1400	4000	2200	0.55	0.37	322	
	1450	3900	2000	0.51	0.36	329	
Mn—	1200	2500	1600	0.64	2.95	100	N_2(g) fired—slow cooled (N_2(g))
	1300	3200	2200	0.68	0.89	160	
	1400	3400	2500	0.74	0.88	210	
	1450	3500	2800	0.80	0.63	260	

the coercive force about ten times as small as that of the basic Ni-ferrite. The air-fired, slow-cooled cycle proved to be the best of the firing conditions.

3. *Mn-Ferrite (Fig. 9):* The beginning of ferrite formation, as can be seen from the hysteresis loops, is delayed in the air-fired samples. This is in agreement with the solid state reaction studies previously described. The loops differ only slightly in appearance at 1100°C, while at 1400°C the loop of the air-fired, slow-cooled sample differs remarkably from the samples fired in air and quenched and from the samples fired in nitrogen and slow-cooled. This is contrary to results obtained in Ni- and NiZn-ferrite. Maximum flux density is slightly lower than that of NiZn-ferrite, whereas the coercive forces of each are comparable. It can be observed that the Mn-ferrite exhibits a much better rectangular-shaped hysteresis loop than NiZn-ferrite.

Evaluation of Hysteresis Loops: Results of a more detailed evaluation of the loops of these three ferrites are shown in Figs. 11-14, where B_m, H_c, B_r, and μ_i for the three ferrites are plotted as a function of formation temperature. A set of three curves is given for each ferrite corresponding to each of the different firing conditions.

1. *Maximum Flux Density B_m:* For Ni-ferrite, the optimum B_m for all three firing cycles occurs at 1400°C. The sample that was air-fired and slow-cooled gave the highest value of about 1700 gauss. At a higher firing temperature, the B_m of this sample decreases, perhaps as a result of decomposition and consequent Fe_2O_3 formation. The quenched sample and the nitrogen-fired sample both attain a constant value for B_m of about 1500 gauss and are less sensitive to over-firing. For NiZn-ferrite, with a firing temperature between 1300°and 1400°C, a much higher value for B_m (4000 gauss) is achieved. The effect at 1400°C of the different firing conditions on the magnetic properties of these ferrites is very small. In Mn-ferrite it can be seen that of the three types of fired bodies the nitrogen-fired and the air-fired, air-quenched bodies show the highest B_m values. A maximum flux density of 3500 gauss can be obtained for these bodies, when fired at 1400°C, a value comparable to that obtained from NiZn-ferrite.

2. *Coercive Force H_c:* The coercive force decreases very rapidly with increasing firing temperature. For Ni-ferrite $H_c = 5$ is attained at 1450°C, and it seems that a further decrease could be obtained at higher temperatures. At about 1400°C the coercive force for NiZn-ferrite reaches a constant value of 0.25, which is twenty times smaller than the value found for the basic Ni-ferrite. At 1450°C H_c for Mn-ferrite has decreased to 0.63, which is about equal for all samples regardless of firing method. For ferrite samples fired in nitrogen at 950°C, the lower value of H_c is found in the case of Mn-ferrite.

3. *Residual Induction B_r:* B_r varies in the same way as B_m with firing temperature. In Ni-ferrite, the change in B_r is very sharp between 1300°C and 1400°C; the air-fired slow-cooled samples show the largest value of B_r. At temperatures higher than 1400°C B_r decreases rapidly, indicated by flattening of the loop. The maxima of the curves are broader for NiZn-ferrite, which indicates that fluctuations of firing temperature in the 1200°C to 1400°C range are not critical. In Mn-ferrite, B_r is enhanced by firing in a nitrogen atmosphere. When Mn-ferrite is compared with the two other ferrites, no maximum is observed and B_r increases steadily.

4. *Initial Permeability μ_i (1kc):* Initial permeability increases in the same manner with increasing firing temperature as B_m and B_r. The shapes of the μ_i-curves for Ni-ferrite are very similar; the highest value of 29.5 is obtained with firing in air and slow cooling. NiZn-ferrite shows a maximum value of $\mu_i = 325$, which is one order of magnitude higher than for Ni-ferrite. A maximum value of $\mu_i = 250$ was obtained for Mn-ferrite at 1450°C with firing in a nitrogen atmosphere.

Discussion

Studies of formation of Ni-, NiZn-, and Mn-ferrites from their constituent oxides by solid state reaction reveal that the beginning of ferrite formation, as observed by X-ray diffraction, occurs at temperatures below 1000°C. After firing at 1250°C, the reaction is completed. At this temperature, as determined by magnetic measurements, magnetic property values of all the ferrites fall far short of optimum. Firing temperatures up to 1400°C (Ni, NiZn-ferrite)—and 1450°C or slightly higher (Mn-ferrite) at the favorable firing condition—are required to obtain ferrite materials with the best possible properties. Of the three firing conditions selected in this investigation, the air-fired and slow-cooled cycle is best for synthesis of Ni- and NiZn-ferrite. The best method for the synthesis of Mn-ferrite is the nitrogen-fired, slow-cooled cycle.

Table III summarizes the magnetic data for ferrites, which were prepared under the most favorable conditions. The data given are for four firing temperatures, 1200°C, 1300°C, 1400°C, and 1450°C. It will be seen that the highest values for B_m and B_r (for the firing cycles indicated) are attained at firing temperatures of 1400°, 1400°, and 1450°C (or higher) for Ni-, NiZn-ferrite, and Mn-ferrite, respectively. The values for H_c and μ_i indicate continuous improvement as the firing temperature in-

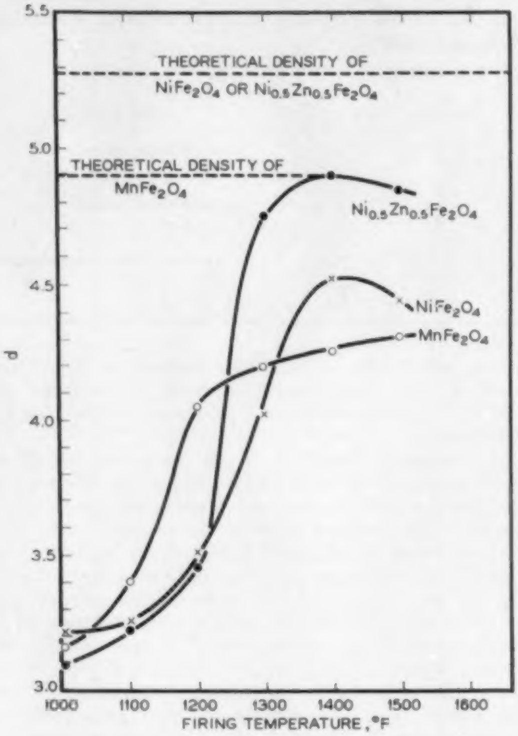


Fig. 15—Density of Ni-, NiZn, and Mn-ferrite as a function of firing temperature.

creases. There might be even further improvement if higher firing temperatures could be obtained. The ration B_r/B_m, which is indicative of the squareness of the hysteresis loops, is included. It is apparent that Mn-ferrite would be the basis of good rectangular-loop material. It is known that this ferrite, when in solid solution with other ferrites (Zn- or Mg-ferrite), shows a nearly perfect rectangular hysteresis loop.

As was demonstrated, the furnace atmosphere can influence the magnetic properties of all these ferrites. Firing in air supports oxidation, while firing in an inert atmosphere, such as nitrogen, supports reduction. In all the magnetic ferrites except magnetite, it is supposed that iron is present in the trivalent state and that reduction would change the valence state from Fe^{3+} to Fe^{2+} (formation of $Fe_3O_4 = FeO \cdot Fe_2O_3$). Oxidation of the Fe-ion to a valence state higher than 3 is questioned. Therefore, with respect to the Fe-ion only, an oxidizing atmosphere such as air would be the most promising. For Ni- or NiZn-ferrite, where any change of the valence state of Ni or Zn in the spinel structure can be considered negligible, air firing and slow cooling would again be the best choice, which was proved by these experiments. In the case of Mn-ferrite, air firing would support oxidation of the Mn-ion resulting in a valence state change for Mn^{2+} to Mn^{3+} (formation of Mn_2O_3 or Mn_3O_4) or Mn^{4+} (less likely at high temperatures). Accordingly, firing in a reducing atmosphere would be required; to maintain the Fe-ions in the +3 state, however, an oxidizing atmosphere would be required. The experimental results prove that prevention of oxidation of the Mn-ion is more important; the nitrogen-fired sample gave the best magnetic properties for the Mn-ferrite bodies.

Density of the fired bodies (Fig. 15) increases rapidly as the firing temperature increases and reaches, for Ni- and NiZn-ferrite, a maximum at about 1400°C; it then slowly decreases owing to decomposition of the material. The density of Mn-ferrite is still increasing at high firing temperature. Under the experimental conditions set up for this investigation, densities of 85 pct, 92 pct, and 87 pct of the theoretical density were obtained for Ni-, NiZn-, and Mn-ferrite, respectively. When Figs. 11-14 are compared with Fig. 15, the density may be observed to change along with the magnetic properties. When density is plotted against magnetic properties for corresponding firing temperatures, there is a nearly linear relationship except in the lowest and highest temperature regions. In the former the reaction is not completed, and in the latter, decomposition in addition to density is affecting the properties. Ideally, ferrites such as Mn, Ni or NiZn contain these cations in the divalent state and iron is in the trivalent state. Departures from these states are considered here as decomposition. As the sintering temperature is increased in ferrites, there is a tendency for the oxygen content to change.[5, 6] Trivalent iron is reduced to divalent iron in magnetite above 1400°C in air. When other cations are present, the tendency toward oxidation will vary. Ferrites have an equilibrium oxygen pressure that usually increases with temperature. Decomposition has been observed at the surface of ceramic pellets of Mn-ferrite.[5] In fact, decomposition of Mn-ferrite also occurs in the bulk, as demonstrated by a change in the lattice constant observed on central portions of the pellets. Mn-ferrite may decompose by either an oxidation or reduction. Chemical analysis should indicate an increase in the presence of either Mn^{+3} or Fe^{+2}. The products in either case will form a solid solution with Mn-ferrite itself. Since lattice constant is sensitive to changes in valence, a change in lattice constant can be expected. The results are qualitatively consistent with the explanation given.

Evidence for the decomposition of Ni- or NiZn-ferrite is demonstrated by the reduction of density and magnetic propertiés above 1400°C. Ni^{+3} and Fe^{+2} are possible oxidation and reduction products. Vitert[7] and Suchet[8] have both shown that either oxidation or reduction can be inhibited by incorporation of small impurities such as manganese, cobalt, or copper oxide. A more detailed analysis is being made of the property changes with density and crystallite size.

Acknowledgment

The authors are indebted to E. Both for making the magnetic measurements, to G. Slotter for preparing the ferrite toroids, and to J. Mellichamp for performing the spectrochemical analysis.

References

[1] E. J. W. Verwey and E. L. Heilman: *Journal of Physical Chemistry*, 1947, vol. 15, p. 174.

[2] P. P. Cioffe: *Review of Scientific Instruments*, July 1950, vol. 21, pp. 624-28. (Cioffe describes an instrument similar to the flux meter mentioned in the present article.)

[3] C. Wagner: *Zeit. Phys. Chem. B34*, 1936, p. 309.

[4] H. Kedesdy and G. Katz: *Ceramic Age*, 1953, vol. 62, p. 29.

[5] H. Kedesdy and A. Tauber: *Journal of the American Ceramic Society*, 1956, vol. 39, pp. 425-31.

[6] W. E. Gorter: Saturation Magnetization and Crystal Chemistry of Ferromagnetic Oxides. *Philips Research Reports*, 1954, No. 9, pp. 321-65.

[7] L. G. Vitert: *Journal of Chemical Physics*, 1956, vol. 44, p. 306.

[8] J. P. Suchet: *Journal of Chemical Physics*, 1956, vol. 24, p. 308.

Discussion of this paper sent (2 copies) to AIME before Sept. 30, 1957, will appear in MINING ENGINEERING and in JOURNAL OF METALS.

Annual Meeting, Society of Mining Engineers of AIME and the Southeastern States Mining Conference

October 15 to 18, 1957, in Tampa, Fla.

Please fill out cards below and return with check to:
B. P. Jones, Registration Chairman, Davison Chemical Co., Bartow, Fla.

Name——————Company——————

Field Trip Reservation

Technical Sessions are held on October 15 and 16; field trips have been scheduled for October 17 and 18 (transportation and lunch are included).

October 17

——Phosphate Field @ $5.00 $———

Includes visit to:
Noralyn Mine of International Minerals & Chemical Corp.
Triple Superphosphate Plant of Davison Chemical Co.
Phosphorus Plant of American Agricultural Chemical Co.

October 18

Alternate Field Trips to:

——Florida Rock Products Inc., Diamond Hill Mine, Brooksville, Fla. @ $7.00 $———

OR

——Cement Plant, Lehigh Portland Cement, Bunnell, Fla. @ $10.00 $———

Name——————Company——————

Deep Sea Fishing Trip Reservation

On Saturday, October 19, a deep sea fishing trip on chartered boat has been scheduled for all who will stay over from the mining conference.

(Transportation and Lunch are included)

——Deep Sea Fishing Trip @ $12.00 $———

Tickets to events, for which you have registered, will be held in your name at registration desk.

Name——————

Registration is free as guest of ——————

Ladies Program

Enclosed is my check in payment for the following:
(Please indicate number of tickets desired)

October 16

To Gulf Beaches for Luncheon and Fashion Show ——— @ $6.00 $———

October 17

To Cypress Gardens for Luncheon and Water Ski Show ——— @ $6.00 $———

October 18

Luncheon in Siboney Room, Columbia Restaurant ——— @ $4.00 $———

The cost of transportation is included above.
Tickets to the events, for which you have registered will be held in your name at registration desk.

Name——————Company——————

Address——————

Registration

Annual Meeting of the Society of Mining Engineers of AIME and The Southeastern States Mining Conference

October 15, 16, 17, and 18, 1957, Tampa, Fla.

Please fill out and mail all cards to:

B. P. Jones, Registration Chairman
Davison Chemical Co.
Bartow, Fla.

(Please indicate number of tickets desired)

——Advance Member Registration @ $5.00 $———

——Advance Nonmember Registration @ $7.50 $———

——Advance Student Registration—Technical Students (Free)

Name——————Company——————

Address——————

Request for Hotel Reservation

Hotel Accommodation Desired

Single——— Double——— Twin Bed ———

Single Bedroom and Parlor Suite———

Double Bedroom and Parlor Suite———

Prefer Motel ——————

Type of motel accommodation desired ———

Date of Arrival——————Will arrive ——Before Noon ——After Noon ——After 6 pm

Date of Departure——————

Acknowledgment of your reservation will be mailed to you by the hotel unless otherwise requested.

Name——————Company——————

General Program

Tuesday October 15

——Welcoming Luncheon 12:00 noon @ $3.50 $———

——Cocktail Party 6:00-7:30 pm (Free with registration)

Wednesday October 16

——Phosphate Breakfast 8:30 am @ $3.00 $———

——Minerals Luncheon 12:00 noon @ $3.50 $———

——Banquet and Entertainment 7:15 pm @ $8.50 $———

Thursday and Friday
(See Field Trip Reservation)

Tickets to events, for which you have registered will be held in your name at registration desk.

Registration

Field Trip

Hotel Reservation

Fishing Trip

General Program

Ladies Program

AIME OFFICERS:

PRESIDENT—GROVER J. HOLT
PAST-PRESIDENT—C. E. REISTLE, JR.
PRESIDENT-ELECT—A. B. KINZEL
VICE-PRESIDENTS—E. C. BABSON, W. A. DEAN, L. E. ELKINS, J. L. GILLSON, W. W. MEIN, JR., ROGER V. PIERCE
TREASURER—C. R. DODSON
SECRETARY—ERNEST KIRKENDALL

AIME STAFF:

ASS'T. SECRETARIES—J. B. ALFORD, H. N. APPLETON, R. W. SHEARMAN
ASS'T. TREASURER—P. J. APOL
FIELD SECRETARY & ASS'T. SECY.—R. E. O'BRIEN, 707 NEWHOUSE BLDG., SALT LAKE CITY 1, UTAH

News of . . . Society Institute Profession

Solid Fuels Conference Scheduled for October

The city of Quebec in Canada will be the site of the 20th Annual AIME-ASME Joint Solid Fuels Conference scheduled for Oct. 10 to 11, 1957. A tentative technical program has been set. The first morning will be devoted to a discussion of the influence of the St. Lawrence Seaway, followed by papers on the consumption of industrial coals in Canada. Thursday afternoon's program will stress continuous coal mining systems, dust control for mechanized underground mining operations, and the flow of coal in bins.

On Friday, these topics will be considered: pelletizing of fine coals, calcination of anthracite, and problems in freezeproofing North Dakota lignite. In the afternoon, participants will investigate the use of competitive fuels, sound methods of solid fuels evaluation, and the use of gravity methods for cleaning fine sizes of bituminous coal.

John Cameron Fox has been appointed Secretary, Society of Mining Engineers of AIME, replacing Arnold Buzzalini who resigned in order to return to private industry. For biographical data on Mr. Fox, see p. 737.

Price Increased For New Petroleum Statistics

The price of *Statistics of Oil and Gas Development*, Vol. 11, has been raised from \$5.00 to \$7.50 for members and from \$10.00 to \$15.00 for nonmembers. The old prices were listed in the December 1956 issue of MINING ENGINEERING, in accordance with the old Bylaws of AIME which stipulated that prices of AIME publications appear in the December issue each year. However, at the meeting of the Executive Committee of the Petroleum Branch on Feb. 25, 1957, this price increase was voted. Approval of this increase was later voted by the AIME Executive Committee on Apr. 15, 1957.

W. B. Stephenson To Represent AIME in Stockholm

Elmer W. Pehrson, chief of the Foreign Activities Div., U. S. Dept. of the Interior, has been given the honor of delivering the opening lecture to the International Mineral Dressing Congress in Stockholm, Sweden, on September 18. MBD Chairman W. B. Stephenson, who is the official AIME representative, has also been appointed a member of the honorary committee of the Congress which is scheduled for September 18 to 21.

W. B. STEPHENSON

The technical program will include eight sessions at which time 33 papers, representing 11 countries, will be read. The following subjects will be covered: comminution, classification and gravity separation, magnetic concentration, roasting and sintering; flotation of sulfide and nonsulfide ores, flotation theory, and mineral processing by chemical methods. In addition to these topics, a miscellaneous clean-up session is also on the agenda.

Several U. S. authors are contributing papers to the technical program. They are: H. W. Hitzrot, T. E. Ban, F. W. McQuiston, J. B. Clemmer, J. P. Grothe, and B. H. McLeod.

AIME Colorado Section Plans Rocky Mountain Minerals Conference

E. H. CRABTREE

Sponsored by the AIME Colorado Section, the Rocky Mountain Minerals Conference will be held in Denver Oct. 30, 31, and Nov. 1, 1957. Tentatively scheduled is a symposium on uranium metallurgy which should serve as a forum for reviewing the alternative methods now available for the extraction of uranium.

For this fourth annual meeting, E. H. Crabtree will be general chairman, assisted by R. L. Scott. Other conference committee chairmen are: L. J. Parkinson, program; C. L. Barker, arrangements; G. M. Wilfley, entertainment; Arthur L. Hill, finance; and Fred L. Smith, secretary. Mrs. J. Paul Harrison is chairman of the ladies' activities.

In the Colorado Section, Asher H. Patten is chairman; Truman H. Kuhn, vice chairman; and William L. Miles, Jr., secretary-treasurer.

Nominations for officers of the Society of Mining Engineers of AIME will appear in the August issue. These officers, if elected, will take office in February 1958.

Nominations Are Announced for 1958 AIME Officers

Three Society Nominating Committees Present Slate for 1958 Institute Officers and Directors

For President-Elect

H. C. PYLE

Howard C. Pyle has been nominated to serve as AIME President-Elect in 1958. Mr. Pyle has been nominated by the Society of Petroleum Engineers of AIME, the Society designated to nominate the 1959 President of AIME. The Society of Mining Engineers will designate the 1960 President and The Metallurgical Society the 1961 President. Born in Williams, Ariz., Mr. Pyle graduated from the University of California with a B.S. degree in petroleum engineering and geology in 1926, later obtaining professional and masters degrees in petroleum engineering from the University of Southern California. Chairman of the AIME Petroleum Branch in 1947, Mr. Pyle has been serving the Institute as a Director since 1955. President, director, and chairman of the executive committee, Monterey Oil Co., since 1952, he is also director of the American Petroleum Inst. and the Western Oil & Gas Assn. During World War II he served as Captain in the office of Chief Engineers, and was sent to England on assignment to the General Staff of Supreme Commander Eisenhower. In the early days of the invasion, he was in Normandy to coordinate the initial imports of bulk fuel. Promoted to Lieutenant Colonel in 1944, he returned home after V-E Day. From 1945 to 1947, as vice president, Bank of America, Mr. Pyle was in charge of the bank's oil industry loans. He served as president of Continental Consolidated Corp. from 1947 to 1950 before opening his own office as consulting engineer in Los Angeles. From 1951 to 1952 Mr. Pyle was president and director of Jergins Oil Co. A member of the Conservation Committee of California Oil Producers Committe, and its Allocation Committee, he served this organization as chairman in 1942. Mr. Pyle has had many of his technical papers published by other technical societies as well as AIME.

For Vice Presidents and Directors

A. W. THORNTON

J. C. KINNEAR, JR.

Arthur W. Thornton, assistant to vice president-operations, National Tube Div., U. S. Steel Corp., Pittsburgh, has been nominated by The Metallurgical Society of AIME as AIME Vice President for one year. The Society of Mining Engineers and the Society of Petroleum Engineers are each represented by two incumbent Vice Presidents. Currently a Past-President of The Metallurgical Society of AIME and Director of AIME, he also served as chairman of the Metals Branch Council during 1956-1957, taking an active part in the organization of the new Society. His efforts were directed toward developing and correcting The Metallurgical Society Bylaws; detecting their structural flaws, he aided in the solution of drafting problems. Mr. Thornton is a former chairman of ISD and has served on the executive committee of the NOHC and on the AIME Bessemer Committee (also the AIME Converter Steel Committee, and now the Acid Converter and Basic Oxygen Steel Committee). A native of McKeesport, Pa., Mr. Thornton graduated from Lehigh University in 1931 with a degree in metallurgical engineering. He was associated with the Weirton Steel Co., Weirton, W. Va., before joining the metallurgical department of Duquesne Works, U. S. Steel Corp. Since 1934 he has been with the National Tube Div., assuming his present post in 1954.

John C. Kinnear, Jr., general manager, Nevada Mines Div., Kennecott Copper Corp., McGill, has been nominated by The Metallurgical Society to serve as AIME Vice President for one year and as a Director for three years. He is the first President of The Metallurgical Society. A native of Nevada, Mr. Kinnear was born in McGill in 1914 and graduated from Pomona College, Claremont, Calif., with a B.S. degree. He went on to obtain a B.S. in metallurgy in 1938 at Massachusetts Institute of Technology, where he first joined AIME as a Student Associate. During his summer vacations he worked for Nevada Consolidated Copper Corp. Mr. Kinnear's main professional association has been with Kennecott Copper, beginning in the company's McGill Smelter. Transferring to the Chino Mines Div., Hurley, N. M., in 1939, Mr. Kinnear was present at the blowing in of the Hurley smelter. He became assistant superintendent of the smelter in 1942. Promoted to assistant to the general manager, Mr. Kinnear returned to McGill, Nev., in 1948, and became assistant general manager, Nevada Mines Div., in 1949. He assumed his present duties as general manager in 1950. Active in AIME both on the Local Section and National levels, Mr. Kinnear has served as chairman of the Nevada Section and as chairman of EMD.

For Directors

Elmer A. Jones, first President of the Society of Mining Engineers of AIME, has been nominated by that Society to serve as AIME Director for three years. Manager of Southeast Missouri Div., St. Joseph Lead Co., Mr. Jones is a native of Minneapolis where he was born in 1902. After graduating from the University of Minnesota School of Mines in 1924 with a degree in mining engineering, he began his career with the Minnesota State Highway. From 1925-1926 he worked for what is now part of Tennessee Copper Co. in Ducktown, Tenn. Elmer Jones began his long association with St. Joe in 1926. Before assuming his present position he had served the company successively as mine surveyor, safety inspector, mine engineer, and assistant general mine superintendent. Two of his AIME technical publications have dealt with the subject of mine mechanization at St. Joe.

The second Director representing the Society of Mining Engineers will be the 1958 President of the Society. At press time for MINING ENGINEERING, the future President of the Society of Mining Engineers of AIME had not been named.

Basil P. Kantzer, vice president in charge of the Gulf Div., Union Oil Co. of California, has been nominated by the Society of Petroleum Engineers of AIME to serve as AIME

E. A. JONES

B. P. KANTZER

Director for three years. Mr. Kantzer will become President of the Society of Petroleum Engineers in 1958. Born in Salt Lake City, he received his B.S. degree in petroleum engineering from Stanford University in 1934. Mr. Kantzer began his engineering career with Union Oil. Progressing rapidly, he was promoted to division foreman at Bakersfield, Calif., in 1942, and chief production engineer in 1943, becoming manager of the California field operations in 1948. Mr. Kantzer assumed the post of manager of natural gas and gasoline for the entire company in 1950. By 1955 he was managing operations for Union Oil's Gulf Div. with headquarters in Houston. He has served as Pacific Coast Local Section Chairman for AIME.

John P. Hammond, assistant general superintendent, Production Dept., Amerada Petroleum Corp., has been nominated by the Society of Petroleum Engineers of AIME as AIME Director for three years. He is now President of the Society. A native of Oklahoma, Mr. Hammond graduated from the University of Tulsa in 1932, at which time he joined his father as an independent oil operator. However, in 1941 he took the opportunity to join Amerada, working for the company in Louisiana and New Mexico. In 1943 he was transferred to the Tulsa headquarters as assistant to the chief engineer, serving in this capacity until 1949, when he became assistant to the vice president in charge of production. Mr. Hammond assumed his present post in 1951. He has led an active professional life, serving AIME as chairman, Mid-Continent Section, Petroleum Branch Publications Committee, and was vice chairman, Petroleum Branch, in 1953.

Walter R. Hibbard, Jr., manager of alloy studies, General Electric Research Laboratory, Schenectady, has been nominated by The Metallurgical Society of AIME as AIME Director for three years. He is now serving as vice president of The Metallurgical Society of AIME, and chairman of IMD for 1957 and will be President of The Metallurgical Society in 1958. A native of Bridgeport, Conn., Dr. Hibbard graduated from Wesleyan University in 1939 with a degree in physical chemistry, receiving his doctorate in physical metallurgy from Yale University in 1942. After three years with the metallurgical section of the Bureau of Ships, USN, he returned to Yale as an assistant professor. He is presently an adjunct professor of metallurgical engineering at Rensselaer Polytechnic Institute. Dr. Hibbard joined the staff of General Electric's Research Laboratory in 1951. He received the AIME Rossiter W. Raymond Award in 1950.

J. P. HAMMOND

W. R. HIBBARD, JR.

Incumbent AIME Officers and Directors as of March 1958:

The President of AIME for 1958 will be Augustus B. Kinzel.

Past-President in 1958 will be Grover J. Holt.

Vice Presidents for 1958 will be R. V. Pierce and J. L. Gillson, *Society of Mining Engineers;* and E. C. Babson and L. E. Elkins, *Society of Petroleum Engineers.*

The following will continue to serve as AIME Directors for 1958: A. Fletcher, F. J. Meek, L. Campbell, F. Strandberg, and Lamar Weaver, *Society of Mining Engineers;* C. R. Dodson, G. F. Moulton, and T. C. Frick, *Society of Petroleum Engineers;* R. B. Caples, C. R. Kuzell, A. W. Thornton, and J. S. Vanick, *The Metallurgical Society.*

The **Chairmen** of the three Society Nominating Committees have announced nominations for AIME President-Elect, Vice Presidents, and Directors for 1958.

Each of the Society Bylaws provides for additional nominations. (The Bylaws of each Society in substantially final form have been published in the Journals and in revised form in the soon to be published 1957 Institute Directory.) If no alternate slate is proposed, no letter ballot will be necessary and the selections of the three Nominating Committees will be declared elected in accordance with the respective Society Bylaws well in advance of their installation at the 1958 Annual Meeting in February.

Annual Meeting of CIM in Ottawa Draws Large Attendance

Chatting between sessions are, left to right: J. L. Ramsell, Kerr Addison Gold Mines Ltd.; Alan Scott, M. J. O'Brien Ltd.; J. M. Cunningham-Dunlop, Nipissing Mines Co. Ltd.; A. E. Cave, New Calumet Mines Ltd.; and AIME President Grover J. Holt.

Following the trend of the times in institute meetings, the 59th Annual General Meeting of the Canadian Institute of Mining and Metallurgy, held at the Chateau Laurier in Ottawa from April 22 to 24, was the largest annual meeting yet held. Attendance set a new record with 1307 men and 531 ladies present.

Representing AIME were President Grover J. Holt and Secretary Ernest Kirkendall, President Holt bringing greetings to the CIM at the Monday welcoming luncheon.

The technical sessions held during the meeting were numerous and well attended, with outstanding papers offered. Monday morning was devoted to divisional business conferences, and that afternoon a general session treated the subject of the St. Lawrence Seaway to which a field trip was scheduled the next day. In addition, a particularly informative color film of the project was shown.

St. Lawrence Seaway

The history of the effort to make the St. Lawrence an economic avenue of transportation goes back to 1700 when the first attempts were made to get a canal built at Lachine. From 1800 to 1848 a 9-ft canal system was completed. By 1901 a 14-ft system had replaced the earlier canals; and by 1959 the 27-ft draft system, the St. Lawrence Seaway, should be completed, after five years of construction. The principal commodities carried will be iron ore westward and grain eastward, but a through water route from the Atlantic to Great Lakes ports will offer more economic transportation for much other freight as well. No dearth of markets for the 2,200,000 hp that will be developed is now anticipated.

Technical Program

Tuesday morning simultaneous technical sessions were held on geology, industrial minerals, mineral dressing, iron and steel metallurgy, and ore and coal mining mechanization. In the afternoon there were also five sessions on coal, geology, petroleum and natural gas, extractive metallurgy, fatigue of metals, and pillar mining. Wednesday morning there were again five separate sessions, this time on geology, industrial minerals, mineral dressing, metal mining, and mineralogy; and that afternoon the technical program featured two geological sessions.

Social Program

A full social program had been arranged: a reception on Sunday night; pre-luncheon cocktails on Monday, Tuesday, and Wednesday for all registrants; a variety show Monday night, also attended by the distaff, which was followed by dancing; the annual dance and president's reception on Wednesday; and general luncheons all three days. In addition the ladies took a tour of the Parliament buildings, a drive through Ottawa, and also enjoyed two afternoon tea parties.

AIME Winner

Francis R. Joubin, an AIME member of Toronto, received the Selwyn G. Blaylock Medal for outstanding work in Canadian exploration geology during the last five years, and particularly for his "direction of the discovery and early development of the Blind River uranium field."

ROCK IN THE BOX

News of M.G.G. Division

One of the most important functions of the MGG Division is preparation of technical programs for presentation at the Annual Meeting of AIME. The next session will be held in New York, Feb. 16-20, 1958. R. H. Feierabend is the Divisional Program Chairman and is assisted by John G. Hall, Program Chairman for the Mining Subdivision; T. N. Walthier, Program Chairman for the Geology Division; and Herbert E. Hawkes, Jr., Program Chairman for the Geophysics Subdivision.

We would like to have you become acquainted with these active AIME members from the pictures and biographical material presented below.

It is a distinct honor to be invited to participate in one of these AIME program sessions, and the committee is already planning an outstanding schedule for New York. They plan sufficient sessions to profitably occupy your time, but will eliminate conflict as much as possible. There will probably be one day of joint program effort for mining, geology, and geophysics similar to that experienced in New Orleans.

Authors wishing to participate in the New York program are invited to contact the various program chairmen, indicating the subject they would like to discuss and comment on their own professional background.

Ray Feierabend has a constructive suggestion regarding preprints of session papers, and we would appreciate the reaction of our membership. Quoting Ray—"The present preprint envelopes used at Annual Meetings are 'for the birds'."

Those of you who have attended an Annual Meeting realize that under present practice you do not receive the papers that particularly interest you. He suggests that all papers to be presented be preprinted by AIME according to some standard specification, so they could be easily handled and filed for ready reference. Those attending an Annual Meeting would be entitled to a certain number of papers. Others could be obtained at a nominal cost. These papers would be available to all the membership at a small fee. The preprint program might be self-sustaining or possibly could have financial help from the division. This is *thinking out loud,* so please send your ideas to Ray Feierabend——NOW!

—Clark L. Wilson
Chairman, MGG Division

MGGD Program Chairman—R. H. Feierabend, who will coordinate the activities of the three Subdivisions, is a native of Little Rock, Ark. A graduate of Columbia University where he received his B.A., Mr. Feierabend also studied at Columbia School of Mines, obtaining a degree in mining engineering in 1942. After graduation he began his long association with Freeport Sulphur Co., beginning as junior engineer in Hoskins, Texas. A series of promotions to field engineer, production engineer, and production superintendent led to the post of general superintendent of Grande Ecaille Mine in 1953. Since last January he has been stationed in the company's headquarters in New Orleans. Mr. Feierabend has served AIME on the National Membership Committee, the Mining Subdivision Program Committee, and was also on the Field Trips and General Committee for the Annual Meeting in New Orleans.


R. H. FEIERABEND


J. G. HALL

Mining—John G. Hall hails from Omaha, Neb., where he was born in 1917. After graduating from the University of Utah in 1939 with a degree in mining engineering, he began his career at U. S. Smelting & Refining Co., where he was successively mucker, mine foreman, geologist, and efficiency engineer. In 1946 he became associated with the Chief Consolidated Mining Co. as general superintendent of operations in Eureka, Utah. Mr. Hall left in 1952 to join National Lead Co. as assistant plant manager of the titanium plant in Tahawus, N. Y., becoming manager in 1955. He has served AIME as program chairman of the Adirondack Section. Mr. Hall's technical articles have appeared in MINING ENGINEERING.

Geology—T. N. Walthier is a native New Yorker and received his B.A., M.A., and Ph.D. degrees at Columbia University. After summer stints as party chief for the Newfoundland Geological Survey and the Labrador Mining & Exploration Co., he became supervising geologist for the Iron Ore Co. of Canada. Mr. Walthier also taught at Brown University and New York University. Later he was staff geologist for the AEC Raw Materials Div., and at present is senior geologist, Bear Creek Mining Co., Morristown, N. J.


T. N. WALTHIER


H. E. HAWKES, JR.

Geophysics—H. E. Hawkes, Jr., born in New York is a graduate of Dartmouth in 1934. After three years in Canadian exploration geology and geophysics, he returned to school, obtaining a Ph.D. from Massachusetts Institute of Technology in 1940. From 1940 until 1953 Mr. Hawkes was associated with the U. S. Geological Survey, working first on the strategic minerals program, then on the development of the airborne magnetometer. In 1946 he became chief of the geochemical prospecting unit. Since 1953 Mr. Hawkes has been teaching geology and geophysics at MIT. In September 1957, he joins the staff of the University of California at Berkeley to lecture on mineral technology.

► The Chairmen of the Division and Subdivisions are continuing their study of MGG Bylaw revision. Progress is being made and we hope to have suggestions for the membership in the very near future.

Bylaws of the Coal Division, Society of Mining Engineers of AIME

Approved by AIME Directors March 21, 1930. Amended and approved at meeting in New York, Feb. 18, 1930. Amended Charleston, W. Va., Oct. 31, 1944. Amended Feb. 1, 1946 and July 8, 1946. Amended June 15, 1948. Amended May 11, 1953. Amended Cleveland, Ohio, May 14, 1957.

(Note: Proposed amendments are italicized.)

Article I
Name and Objects

Section 1. This Division shall be known as the Coal Division *of the Society of Mining Engineers of AIME.*

Section 2. The object shall be to furnish cooperation among those interested in any way in coal, and to promote the advancement of this branch of the AIME work through meetings and for the reading and discussion of professional papers connected therewith.

Article II
Members

Section 1. Any Member, Associate, or Junior Member of the AIME in good standing may become a Member, Associate, or Junior Member of this Division upon registering in writing a desire so to do.

Section 2. But no one who had been continuously indebted to the AIME or to this Division for more than *three* months shall be entitled to vote or to receive publications to which, as a member of the Division, he would be entitled.

Article III
Dues and Assessments

Section 1. Dues or assessments may be fixed by the Executive Committee of the Division, subject to the approval of the majority of the members of the Division and the Board of Directors of the *Society of Mining Engineers and the Board of Directors of AIME.*

Section 2. Funds of the Division shall be deposited by the Treasurer in a bank account in the name of the Division, and may be paid out of this account only by check signed by both the Treasurer and the Chairman, and only for such purposes as have been authorized by the Executive Committee. Exceptions to this general rule can be made by order of the Executive Committee of the Division.

Article IV
Meetings

Section 1. The Division shall meet at the same time and place as the Annual Meeting of the AIME, for the election of officers and the transaction of any other business, and at such other times and places as may be determined by the Executive Committee.

Section 2. At any meeting of the Division, for which notice has been sent to the members of the Division through the regular mail at least *20* days in advance or *10 days if notified by telephone or telegram,* a business meeting *may be* convened by order of the Executive Committee, and any routine business may be transacted not inconsistent with these Bylaws or with the Bylaws of the AIME.

Section 3. For the transaction of business, the presence of a quorum of not less than 15 members of the Division *or ¼ of the Executive Committee* shall be necessary.

Article V
Officers and Government

Section 1. The officers of the Division shall consist of a Chairman, a Chairman-Elect, a Secretary, and a Treasurer. The office of the Secretary and Treasurer may be combined in one person, if desired by the Executive Committee.

Section 2. The government of the affairs of the Division shall rest in an Executive Committee, insofar as is consistent with the Bylaws of the Division and the Constitution and Bylaws of the AIME.

Section 3. The Executive Committee shall consist of the officers, the immediate *three Past*-Chairmen, *Chairman of the Standing Committees;* and nine elected members, nominated and elected as provided hereafter in Article VII. The Secretary of the Division shall act as Secretary of the Executive Committee.

Section 4. The Chairman, Chairman-Elect, and Secretary shall serve for a period of one year, or until their successors shall have been elected. Each member of the Executive Committee elected at the annual meeting shall serve for a period of three years. Any vacancies occurring in the Executive Committee shall be filled by the Chairman *of the Division, the appointee to serve until the next election.*

Article VI
Committees

Section 1. The Standing Committees of the Division shall consist of three technical and four service committees: Technical—Mining, Preparation, Utilization; Service—Publications, Programs, *Scholarship Selection, Scholarship Fund and* Membership.

Section 2. Each member of the Committee on Programs shall be appointed by the Division Chairman and Executive Committee to *preferably* serve for three years.

Section 3. The Chairman of the Coal Division shall recommend to the Institute the chairman and members who shall serve on the Coal Division's Publication Committee.

Section 4. After the initial organization, the chairmen and members of the respective technical committees, except the Publication Committee, shall be selected by the Chairman-Elect of the Division during the year preceding their term of office and shall be appointed at the time of the February Annual Meeting to serve for one year. Any chairman or member of these committees can succeed himself if in the opinion of the Chairman-Elect such repetition will be for the good of the Division and Institute. The Chairman of each committee of the Division can increase or decrease the number of members of these committees with the approval of the Executive Committee.

Article VII
Nominations and Elections of Officers and Committees

Section 1. Every year the Division shall elect a Chairman, a Chairman-Elect, a Secretary and Treasurer, and three members of the Executive Committee.

Section 2. The nominating committee *shall consist of the following members: Chairman of the Division, immediate three Past-Chairmen, and Secretary.*

Section 3. This committee shall make its report to the Executive Committee on or before July 1.

Section 4. Any ten members of the Division may submit nominations

(Continued on page 808)

INDUSTRIAL MINERALS DIVISION

NEWSLETTER

Dear Members of the
Industrial Minerals Division:

Tom Kesler and your new slate of officers took office as scheduled at the Executive Meeting in New Orleans and the transfer of the responsibility and activities from the 1956 officers was made most efficiently. A high spot of the New Orleans meeting was the field trip to America's largest sulfur operation and the Port Sulphur shipping facilities. Ray Feierabend, of Freeport Sulphur, should be congratulated on the good planning that went into this field trip.

Credit Due

Acknowledgment should be made of the many forward steps of the Division under the leadership of Ray Ladoo. Perhaps the most prominent of these is the compilation of the new Divisional Directory. The Bylaws were revised by John Ames and his committee and approved by the membership. We participated very actively in the first branch meeting of the Society of Mining Engineers of AIME and carried our end of the responsibilities with gratifying results. Tom Gillingham is chairman of our Program Committee and was most active for this meeting. A very special attempt was made to give emphasis to the cement industry and its relation to our Division. The quarterly Newsletter of the Division was also instituted during Ladoo's tenure, and we understand that this is looked on with great favor not only by our membership but by those of other divisions. Also begun during the past year was the revision of the Seeley W. Mudd volume of *Industrial Minerals and Rocks* for its third edition.

Divisional Directory

The directory has been distributed free of charge to all those whose names are lisited therein. The Executive Council of the Division decided at the New Orleans meeting that extra copies, and copies to people not listed in the Directory should be sold at $1.00 each. These may be obtained by writing directly to the Business Office, AIME, 29 W. 39th St., New York 18, N. Y. Comments on the Directory are very complimentary and cover a wide range of interest. The chief metallurgist of a research corporation says:

> *"Allow me to congratulate you on the Directory. It is a very fine piece of work. At the annual meeting in New Orleans, I noticed that MBD was most envious of IndMD Directory."*

A graduate student at a midwestern State college—*"Glad to see this Directory. Congratulations."* A project engineer of a glass manufacturing company—*"Best job of cataloguing ever seen."* Government geologist—

> *"The Committee should be congratulated for issuing the Directory, which has been badly needed, and for figuring out special fields of individuals as far as it did."*

Association executive:

> *"Allow me to express my unqualified compliment on the Industrial Minerals Division 1956 Directory. . . . This Directory will be extremely useful to me both personally and in connection with AIME affairs as well as for other purposes."*

Chief engineer of an industrial minerals concern:

> *My compliments to IndMD for the excellent job done in producing the first edition of the Directory."*

These unsolicited comments should make Tom Gillingham and his committee feel that it was all worthwhile. The second edition of the IndMD Directory will again list the members' names and addresses as well as a complete commodity interest index. If you have not yet returned your *commodity interest listing* questionnaire, please do so in order that you may be listed correctly in the second edition. S. S. Cole, past-chairman of IndMD, heads the new Directory Committee and is assisted by John B. Graham and Pauline Moyd. It is expected that the second edition will be available some time this fall, but we will have more news on this in our next Newsletter.

Reactions from the membership on the Newsletter are equally as complimentary but this is a case where actions will speak louder than words. The Newsletter will thrive in direct proportion to the information we receive from the membership. Please send your written communications to John G. Broughton, Secretary IndMD, AIME, Room 448, New York State Education Building, Albany 1, N. Y.

Editors Appointed

J. L. Gillson, Editor-in-Chief of the new third edition of *Industrial Minerals and Rocks* reports that 11 associate editors have been appointed, each to be responsible for four or five individual subjects. First drafts of the various chapters were due on May 1, and the aim is to have the first composite draft ready for editing in the fall of 1957.

According to the Bylaws of the new Society of Mining Engineers of AIME, each division is to provide members for certain operating committees. The positions and appointments made by Tom Kesler and our nominating committee are as follows: Board of Directors: R. M. Grogan, 3-year term; T. L. Kesler, 2-years; R. B. Ladoo, 1-year. Nominating Committee: A. B. Cummins (Alternate, G. H. Chambers) and N. M. Foose (Alternate, R. C. Stephenson). Admissions Committee: L. P. Warriner and J. B. Graham. Program Committee: T. E. Gillingham. Membership Committee: H. A. Meyerhoff. Mineral Economics Committee: R. B. Ladoo. Transactions Editorial Committee: D. R. Irving. General Editorial Committee: R. C. Stephenson. Education Committee: S. S. Cole.

Since these appointments have been made, Bob Grogan has been designated chairman of the Mining Society's Admissions Committee and Ray Ladoo has been made treasurer of the organization. Kesler also appointed a new Bylaws Committee to consider changes in the Divisional Bylaws made necessary by the formation of the new Society of Mining Engineers. This committee consists of Harold Bannerman, Ian Campbell, and John Broughton, chairman.

Howard Meyerhoff, chairman of our Membership Committee, asked me to remind each of you that his is the largest committee in our Division. He includes each member of IndMD on his committee and earnestly solicits your help, ideas, and suggestions. His address is: Scientific Manpower Commission, 1530 P St. N.W., Washington 5, D. C.

Tom Gillingham is soliciting papers from interested authors which will be suitable for the next Annual Meeting of AIME, Feb. 16 to 20, 1958, in New York. Persons who wish to suggest papers or contribute them should write to T. E. Gillingham, Jr., Bear Creek Mining Corp., 95 Morris St., Morristown, N. J.

The next issue of this Newsletter will bring you up to date on the activities of the May Executive Committee meeting and will have further details of the first annual meeting of the Society of Mining Engineers in Tampa.

J. G. B.

Industrializing the Atom

All engineers and scientists working in the nuclear field are urged to contribute one or more papers to the 1958 EJC Nuclear Congress. There were 158 papers from all aspects of nuclear science and engineering at the 1957 Congress in Philadelphia. Abstracts are due by July 15, 1957, and AIME authors should immediately contact Frank A. Rough, Battelle Memorial Institute, Columbus, Ohio. The 1958 Congress will be held March 17 through 21 in the International Amphitheatre, Chicago.

Around the Sections

AIME President Grover Holt Tours U. S., Visits Local Sections

A highly successful spring tour covering many states and Canada was recently taken by AIME President Grover J. Holt, who visited Local Sections throughout the country, accompanied by AIME Secretary E. O. Kirkendall and Field Secretary Roy E. O'Brien.

First stop was Little Rock, Ark., on March 27, where Governor O. Faubus presented President Holt with an honorary certificate naming him an official "Arkansas Traveler." This visit to the Arkansas Section included tours of the Big Rock Stone & Material Co., Reynolds Mining Corp., and the Mining Div., Aluminum Co. of America.

The following day President Holt was guest of honor at the Tri-State Section Banquet in Miami, Okla. Following a reception in the mezzanine of Hotel Miami, President Holt addressed the dinner guests on the history of the iron ore industry from its infancy to the record breaking years of 1955-1956. He also urged encouragement of engineering students and a closer alliance between the mining industry and student chapters of engineers.

In El Paso, Texas, the Local Section held a dinner in his honor at the Hotel Cortez on March 29. President Holt spent the next two days in New Mexico, dividing his time between Silver City and Carlsbad, before leaving for Los Angeles to spend April 3 there. He arrived in Reno on April 5, in time for the Pacific Southwest Mineral Industry Conference, sponsored by the Nevada, San Francisco, and Southern California Sections, attending the cocktail party and dinner at the Riverside Hotel.

By April 8, he was back east in Pittsburgh, his presence honoring the National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conferences.

AIME President Grover J. Holt became an "Arkansas Traveler," an honor conferred upon distinguished visitors to the state. Shown left to right: Governor Faubus presenting the official certificate to Mr. Holt as AIME Field Secretary Roy O'Brien and Luther Branting, Alcoa, look on.

Turning westward again, he flew to Portland, Ore., to attend the Pacific Northwest Regional Conference in the Multnomah Hotel on April 11. Then, heading north to visit our Canadian neighbors, President Holt represented AIME at CIM's annual meeting in Ottawa, April 22.

During the first two weeks in May, Mr. Holt's itinerary included stops at five local sections. On May 4, he was in the windy city as the Chicago Section turned out in full force to welcome him. The Montana Section held a joint meeting with the Anderson-Carlisle Society in the Museum Hall, Montana School of Mines, Butte, on May 11. As the featured speaker of the evening, President Holt discussed the iron ore industry, and also gave a brief report on the affairs of the Institute. On Monday, May 13, Mr. Holt spoke to the student body at the Montana School of Mines on the topic of research.

Coeur d'Alene Subsection of the Columbia Section was the next port of call for the roving AIME President. The meeting in his honor was held in Kellogg, Idaho, on May 14. One of the highlights during the welcoming dinner for Mr. Holt was the award to Arthur W. Fahrenwald of the honor "Inland Empire Engineer of the Year" for his outstanding achievements in the field of ore dressing. The next two days were spent in Washington where Mr. Holt made two stops, Spokane and Seattle, before winding up his tour in San Francisco on May 20. There, he attended a special President's Meeting in the Engineer's Club, and ad-

President Grover J. Holt, right, was special guest at the luncheon meeting of the Chicago Section executive committee on May 4. Section chairman Michael Tenenbaum, left, led the discussion on plans for Chicago's role as AIME host section during the World Metallurgical Congress, Nov. 2-8, 1957. Another topic considered was the IMD meeting Nov. 4-7, and the ISD special activity meeting on Nov. 5, both slated to be held in the Windy City.

dressed the Section on the "new look" for AIME.

From San Francisco Mr. Holt planned to travel to Billings, Mont., where he would have attended another AIME meeting on his way east. He deplaned to stay overnight in Seattle, and coming into the city the airport limousine in which he was riding was involved in a serious accident hospitalizing many of the passengers. Although his injuries forced him to cancel his attendance at the Billings meeting, his many friends will be glad to hear that he has completely recovered from the effects of the crash, except for a slight scar on his forehead.

• The **Washington, D. C., Section** met for cocktails and dinner on April 2 at the Cosmos Club. Featured speaker was Thomas B. Nolan, director of the U. S. Geological Survey. He summarized some of the current activities of his organization, such as ground water studies, mineral resources investigation, topographic and geologic mapping.

• The South Dakota School of Mines & Technology in Rapid City was the scene of the March 20 dinner meeting of the **Black Hills Section.** The program consisted of a report on the Annual Meeting by Alexander E. McHugh. This was followed by a talk, *Make Mine Safety*, by Howard F. Schmuck, Colorado Fuel & Iron Corp. A film on rock bolting was shown in conjunction with the lecture.

• The **Utah Section** met on March 21, at the Newhouse Hotel in Salt Lake City. At that time the group discussed *The Aneth and Associated Oil Discoveries in the Paradox Basin, San Juan County.* Leading the discussion was W. Don Quigley, assisted by C. W. Hendel, geologists.

• The **Yavapai Subsection** of the Arizona Section held its monthly cocktail hour and dinner meeting at the Hassayampa Hotel, Prescott, Ariz., on March 5. Several AIME members from other districts were present to see the sound color film, *Rock Bolting*, which was shown after dinner by the Colorado Fuel & Iron Corp.

A panel discussion on that subject followed, led by Luke Helms and G. H. Scotney, of CF&I.

• When the **Colorado Section** held their monthly dinner meeting on February 21, at the University Club, Denver, the program was supplied by the AIME Petroleum Section. Featured speaker for the occasion was Fred Mace, Continental Oil Co., Houston, who spoke on *Operation Egypt.* He also presented a film, *Desert Venture* which proved of great interest. Mr. Mace was well equipped to discuss his subject, since he had been stationed in Egypt at the time of the crisis in the Suez Canal area.

George H. Pudlo was the winner of the Old Timers Club award, as the outstanding mining student for the year, at Pennsylvania State University. He was presented with a watch at the Mining Engineering Society Banquet held April 10, at the Hetzel Union Bldg. The award was made by E. R. Price representing the Federal Mine Safety Board of Review, who also gave the principal address of the evening. Mr. Pudlo who hails from Stump Creek, Pa., has served as president of the Society which is the Penn State Student Chapter of AIME. For news of additional awards, see p. 813.

• The **St. Louis Section** held a joint meeting with the Engineers Club of St. Louis on March 28, at which time Edward L. Clark spoke on *Uranium Hunting.* Vice president of exploration and development for Four Corners Uranium Corp., Grand Junction, Colo., Dr. Clark presented a brief geological review of the major uranium areas in the U. S.

• A large turnout of miners and geologists marked the second annual uranium symposium of the **Uranium Section** April 5 to 7 in Salt Lake City. Among the principal speakers were Alan Jones of the AEC in Grand Junction, Colo., who reviewed *Outlook For Uranium*, and G. T. Harley, consulting geologist, who discussed the economics of *Potash in the Paradox Basin.*

• The **Adirondack Section** held its first meeting of the year at Republic Steel Corp., Lyon Mt., N. Y., on April 27. Members had a choice of an underground tour or a trip through the mill and sintering plant. In the evening dinner was served in the American Legion Home, at which time Allan Mogensen gave a talk on *Work Simplification Programs.* Newly elected Section officers for 1957 are: A. L. Hall, chairman; M. Lowry, vice chairman; and C. Dievendorf, secretary-treasurer.

• The **Colorado MBD Subsection** held its annual meeting jointly with the **Pike's Peak Section** on May 11, at the Broadmoor Hotel in Colorado Springs, Colo. The morning was devoted to business meetings, leaving the afternoon free for technical sessions. The papers included a review of the details and experiences of Mines Development Inc. with the resin-in-pulp process in use at their Edgemont mill, presented by G. F. Richards. James Thompson followed with a summary of the practical applications and limitations of the Humphrey's Spiral during the past 15 years. Howard Keil concluded the technical session with a discussion of carbon cyanidation used for gold recovery at the Carlton mill of the Golden Cycle Corp. In the evening, members and guests turned to lighter activities with a gala dinner and dance.

• When the **Chicago Section** met on April 3, at the Chicago Bar Assn., the featured speaker was F. G. Jaicks, assistant general manager Inland Steel Co., who addressed the group on the subject of *Recent Experiments in Continuous Casting of Steel.*

George B. Harrington received the 50 year certificate and medal of the Legion of Honor. The presentation was made by chairman Michael Tenenbaum. Mr. Harrington was the recipient of the William Lawrence Saunders Gold Medal in 1944.

• The **Montana Section** met on March 20 in the Montana School of

(Continued on page 808)

Alaska Section Joins University Ceremonies

To Mark Opening of Memorial Library on Campus

Graduating senior Charles Dunham is shown receiving the engineer's canon of ethics from G. A. Gustafson, chairman of the Alaska Section.

The University of Alaska in College, Alaska, held a banquet on May 15 to mark the formal opening of the Winston Spencer Memorial Library in the school's Brooks Memorial Mines Building. This gathering attended by about 130 persons, also served as a joint meeting of the Alaska Section, the Woman's Auxiliary, the AIME Student chapter, and the School of Mines.

Featured speaker at the banquet held in Constitution Hall, the Student Union Building, was John F. Spielman, Dean of the College of Engineering, Washington State College. Earl Beistline, dean, School of Mines, served as master of ceremonies for the first part of the program. After thanking Norbert Skinner for providing the dinner music, he then introduced several prominent guests. They were: F. C. Lindvall, California Institute of Technology; Fred Merryfield, Oregon State College; Dana Smith, director of metallurgical research, Kaiser Aluminum & Chemical Co.; President and Mrs. Ernest N. Patty of the University of Alaska; and Vice President and Mrs. Robert Wiegman, also of the University.

Dean Beistline then introduced members of various organizations which have contributed scholarships, as well as those who have received these awards. Included were: Mr. and Mrs. R. M. Boyd, Northern Commercial Co.; Stewart Butler; Mr. and Mrs. J. D. Crawford, U. S. Smelting, Refining & Mining Co.; Robert Russell; Mr. and Mrs. H. Strandberg, David and Jenny Strandberg Memorial Scholarship; LeVake Renshaw; William Strandberg, AIME S. W. Alaska Section; Norman Rivard; Mrs. Earl H. Beistline, WAAIME; and Ervon Fairbanks.

Chairman G. A. Gustafson of the Alaska Section then took over and introduced several guests: Judge and Mrs. Vernon D. Forbes; Mr. and Mrs. R. A. Derr; Mr. and Mrs. Woodrow Johansen; Donald Stein, territorial assayer at the College; Val Freeman, geologist in charge, Alaska Branch of the U. S. Geological Survey; Troy Pewe, and Russell Paige, engineering geologists, USGS; Bruce Thomas, USBM, and Mrs. Thomas; and J. A. Herdlick, USBM, Juneau, Alaska.

Chairman Gustafson then presented each graduating senior of the School of Mines with the engineer's canon of ethics. The seniors were Charles Dunham, John Koropp, Harvey Turner, Arne Sundt, and George Vournas. As the outstanding graduating senior in the School of Mines, John Koropp received the annual AIME award, an engraved Brunton pocket transit with appropriate accessories.

In his banquet address, Dean Spielman discussed the need for the mining industry to offer better incentives for attracting mining engineers and geologists in order to compete with other engineering fields. He also urged that mining schools constantly study and, if necessary, revise their curricula to assure that the students will graduate with the best possible background and training.

President Patty eulogized Winston Spencer for whom the library is named. A mining engineering graduate of the University of Alaska, the late Mr. Spencer was accidentally killed while working for the Goodnews Bay Mining Co., producers of platinum. Andrew Olson, president of the company which provided the funds for the library, was then introduced. He presented a portrait of Spencer to the School of Mines.

The program concluded with an open house in the memorial library.

Andrew Olson, left, president, Goodnews Bay Mining Co., presents a picture of the late Winston Spencer to University of Alaska President Ernest N. Patty at banquet marking the opening of the memorial library on campus.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The Engineering Societies Personnel Service was established by the Four Founder Societies, and at one time part of the cost was underwritten by these societies. Currently the ESPS is a nonprofit but self-supporting corporation. A 1956 deficit was paid from a modest surplus and it is hoped that there will be no deficit for 1957. The current employment situation is entirely different from that when the Service was established. More than half of the employers are willing to pay the employment fee, whereas this had formerly been borne by the applicant. It is planned to change the contract entered into by a member with the ESPS in order to take into consideration that in most cases the employer will pay the fee. This change plus publicizing the service will be an added service to a larger number of AIME members. It was also suggested that the ESPS make its services available at some of the larger Institute meetings. These suggestions were approved.

► John C. Calhoun, Jr., chairman of the Council of Education of AIME, was appointed to represent the Institute at the Centennial Convocation of the National Education Assn., to be held in Philadelphia, July 3, 1957.

► It was voted that the members of the Rossiter W. Raymond Award Committee serve as the AIME Noble Prize Committee, with the chairman representing AIME on the intersociety Alfred Noble Joint Prize Committee.

► Syracuse University's request for establishment for a student chapter, and the proposed bylaws, were approved, with one revision in Article 2, Section IV of the bylaws.

Mineral Industry Meetings

Sept. 12-14, Wyoming Geological Assn., 12th Annual Field Conference, Southwestern Wind River Basin, with headquarters in Lander, Wyo. Field trips in area bounded by Winkleman Dome oil field, Rattlesnake Mts., Bison Basin oil field.

Oct. 3-5, Seventh Annual Exploration Drilling Symposium, University of Minnesota, Center for Continuation Study, Minneapolis.

New Project Offers Tips for Job Seekers; Gives Hints on Writing Resumes

Sample Resume

(Sec. I)

ROBERT W. HOWARD
1113 Labelle Road
Westbury, N. Y.

Edgewood 5-6874

(Sec. II)

SUMMARY OF BACKGROUND

Six and one-half years experience as an electrical engineer in the fields of pulse techniques, servo-mechanisms, reliability, environmental analysis, support equipment, specifications, cost estimating, contracts, system synthesis applied to aircraft and missile control systems and bombing and navigation systems. Two and one-half years of this time have been in a supervisory capacity responsible for a 13 man effort.

During 5 years of this period graduate school was attended in the evenings leading to the M.S.E.E. and the completion of all class credits toward the Dr. E.E.

Particularly competent to assume technical, administrative and business responsibilities of either a broad project or of a challenging specialized research nature.

(Sec. III)

Fully qualified by experience and ability for position as

E L E C T R I C A L   E N G I N E E R

P R O J E C T - R E S E A R C H

(Sec. IV)

..Experience.. Record

THE SPERRY GYROSCOPE CO., Great Neck, N. Y.

Initially assigned consulting responsibility on control system synthesis on a subsonic missile and synthesis and development of a barometric and terrain height system concurrent with the assignment to establish the basic principles upon which an effective reliability program for advanced missiles could be based.

The latter effort led to an engineering group leader assignment on an advanced inertial guidance missile on reliability, automatic support equipment, specifications, estimating and contract work. A total of 13 engineers were under my direct supervision for this task.

The reliability effort was of the broadest possible scope including: component selection and test; environmental analyses, such as, transient heat flow resulting from aerodynamic heating and acoustic energy transmission; system analysis and the determination of the need for redundancy; the analysis of environmental test facility requirements and the preparation of specifications for their purchase, etc.

ROBERT W. HOWARD

Resume - page 2

The assignment upon specifications and cost estimating was concerned with the detailed knowledge of military specifications, preparation of systems specifications, preparation of cost estimates upon receipt of a request for a quotation and the preparation of statements of work to accompany the quote.

Following the above, I was assigned the task of advanced system study on a bombing and navigation system leading to the preparation of a proposal and cost estimate for the system. At present, the effort is in the early negotiating stage with the customer and is a multi-million dollar effort. (August 1953 to present)

ENGINEERING RESEARCH CORP., Riverdale, Md.

PROJECT ENGINEER

Assigned to the synthesis, design and development of radar simulators as training aids. Responsible for a 120 vacuum tube unit which required a detailed knowledge of pulse techniques in the 0.1 micro-second to 10 milli-second range. (Oct. 1952 - Aug. 1953)

NATIONAL BUREAU OF STANDARDS, Washington, D. C.
(military Service in the U. S. Army Ordnance Corps)

Drafted in U. S. Army Ordnance Corps in Oct. 1950 and assigned to the National Bureau of Standards on the development of the proximity fuse for bombs, rockets and mortars. The assignment included the design and development of test equipment as well as the synthesis and development of a constant height bomb fuse. The majority of the work was concerned with the design of pulse circuits, signal generators and miscellaneous C.R.T. circuits. (Oct. 1950 - Oct. 1952)

(Sec. V)
Education

College of the City of New York.	Degree: B.E.E., January 1950
University of Maryland.	Degree: M.S.E.E., January 1954
Polytechnic Institute of Brooklyn.	Have completed all course requirements for the Dr. E.E., June 1956 Heavy minor in Solid State Physics.

Personal Data

Born May 13, 1928, New York, N. Y. Married - one child.
Physical characteristics: height - 6 ft.; weight - 190 lbs.; complexion - fair; health - excellent.

After a survey proved the inadequacy of 62 pct of personal resumes for technical and professional positions, Orville E. Armstrong & Co. is offering information on *How to Write Your Resume*.

A resume should cover experience, education, and personal information of direct interest to a potential employer. The brief summary of background must contain a condensation of your entire experience record, accentuating those areas which are directly related to the new position. Vital is the positive statement concerning job objective, pinpointing the resume to a particular job rather than for any opening available.

The booklet emphasizes the importance of omitting information which is not of specific interest to your future employer, as well as personal opinions which are not a part of your employment history or personal background. Also stressed is quality; since the resume arrives first, it must represent you, the writer, in appearance, and speak in your behalf. Spacing and paragraphing must be adequate, and of course, the material should be typed on good quality rag bond paper of standard size—8½x11 in. Resumes and cover letters should be reproduced by a precise offset method in standard typeface.

Although a one-page resume is suggested for lower bracket jobs, this is not a blanket rule for other types of positions. Particularly on management and technical occupational levels, sound judgment as to length of an effective resume must apply. See sample resume above.

New Institute Offers Translations of Russian Technological Research

Pergamon Institute, a nonprofit-making foundation has recently been formed in New York. Its purpose is to make available to English-speaking scientists, doctors, and engineers from all UN countries the results of scientific, technological, and medical research and development in the Soviet Union and other countries in the Soviet orbit.

To be established is a translation panel of competent translators from Russian and other Slavic languages into English. The Institute will charge customers for services on a cooperative cost-sharing plan. It also hopes to encourage the teaching of the Russian languages, to sponsor and foster research into the organization of scientific information, and to publish monographs in English reviewing Soviet scientific activity.

Drilling Symposium At University of Minnesota

The Seventh Annual Exploration Drilling Symposium of the University of Minnesota will be held at the Center for Continuation Study in Minneapolis, Oct. 3 to 5, 1957. The five sessions and the discussion periods will cover geophysical instrumentation of small bore holes, small bore hole surveying, reliability and weighting of drill hole analyses, air and mud drilling, diamonds and synthetics for drill bits, and personnel training and drill standardization. The symposium is jointly sponsored by the School of Mines and Metallurgy, and the Center for Continuation Study. Applications for registration may be obtained by writing to the Center for Continuation Study, University of Minnesota, Minneapolis, Minn.

Mine Safety Conference

The 33rd Annual Safety Conference sponsored by the Lake Superior Mines Safety Council was held May 23 and 24 in the Hotel Duluth, Duluth. Some of the topics considered were: management's attitude toward safety, training for safety, personality factors in safety, potential hazards in smelter and foundry, and underground ventilation.

Toastmaster for the banquet on May 23 was Kenneth Duncan, Pickands Mather & Co., Duluth.

Geophysics Scholarships

The Society of Exploration Geophysicists administers scholarships which total $8850 per year. The latest grant of $500 has been made by the Southern Geophysical Co., Ft. Worth, Texas. The oil exploration firm has stipulated that the scholarship be awarded to a worthy high school student who intends to pursue a course leading toward a career in exploration geophysics.

Applications for any of the nine scholarships to be awarded in 1958 should be received by the Society of Exploration Geophysicists' headquarters in Tulsa, Okla., by June 1958. Application forms may be obtained from the Tulsa office or from any of its local sections.

Colorado Mining School Receives Two Honors

The Colorado School of Mines Foundation Inc. has received a donation of $5000 from the Adolph Coors Co. in support of the school's development program. The third such unrestricted gift, it is being used in the continuing faculty improvement phase of the School's Horizon Plan.

The School of Mines was also honored by Spain's outstanding mineral industries journal, *Mineria Y Metalurgia*, which dedicated its May issue to the School. The magazine included sections on each of the six degree-granting options offered by the School, along with a photo story on each. There is an article on the history of the School, stories on the Horizon Plan, the new library building, coeds on campus, the experimental mine, and the field camp at Ouray.

The journal concludes that the school sets an example that Spain would like to follow.

NOTE

A limited number of copies of *Mining Branch Abstracts*, prepared for the AIME Annual Meeting in New Orleans, Feb. 24-28, 1957, are still available. Copies can be obtained by writing to John C. Fox, Society of Mining Engineers of AIME, 29 W. 39th St., New York 18, N. Y., and enclosing 50¢. Please indicate your Divisional interest at the time you order.

100th Anniversary of Belgian Mining Journal

Mining Engineering congratulates the *Revue Universelle des Mines* on the occasion of its 100th Anniversary in May. The magazine is the organ of the Association des Ingénieurs sortis de l'Ecole de Liège (association of graduates of the University of Liège). It is the oldest Belgian technical periodical.

For this occasion, in response to a suggestion from His Majesty, a special international conference was organized under the title *Scientific Research and Industry*. The conference, under the co-direction of an old friend of AIME, M. Pierre Coheur, featured speakers from six European countries.

Business Courses At University of Michigan

The University of Michigan at Ann Arbor has scheduled a group of courses in management science and computer technology from August 19 to 30. Given by the faculty of the college of engineering, the courses are open to those who have the equivalent of a four-year college course in business, engineering or science.

Classes will be held daily from 8:50 am to 5 pm with occasional evening lectures. A bound copy of the notes will be compiled by the university staff and sent to each student.

Topics to be discussed are: the digital computer; the techniques of probability and statistical inference for solving business problems in which only partial information is available; methods of programming business operations and machine scheduling, and human capabilities and limitations, a complex factor in the industrial scene.

PERSONALS

Frederick C. Kruger has been named chief geologist, Mining and Exploration Dept., International Minerals and Chemical Corp., Chicago, Dr. Kruger, formerly assistant chief geologist for Reynolds Metal Co., Little Rock, Ark., has taught geology at Dartmouth College, and was professor of geology and economic geology at the University of Tennessee.

F. C. KRUGER

B. C. Bellamy was recently honored by the Wyoming Engineering Society on the occasion of his 50th anniversary in the field. The salutation recognized Mr. Bellamy as one of the first 100 licensed engineers in the U. S. His father, the late Charles Bellamy, claimed the distinction of having been the first professional engineer in this country.

James W. Shaffer is now working in the Exploration Dept., Kaiser Aluminum & Chemical Corp., Oakland, Calif.

E. J. Duggan, formerly mill superintendent, has been elected a director of Climax Uranium Co., Climax, Colo.

Merle H. Guise has been traveling in Mexico and is now located at Instituto Allende, Guanajuato, Mexico.

William T. Ahlborg has been named executive vice president and general manager of Denver Equipment Co., Denver. A member of the company since 1938, Mr. Ahlborg was previously vice president and secretary.

R. L. Sayrs has been appointed superintendent of the Flat Gap operation of The New Jersey Zinc Co., Treadway, Tenn.

At Reserve Mining Co., a joint venture of Armco Steel Corp. and Republic Steel Corp., Silver Bay, Minn., **C. L. Kingsbury** is retiring as vice

(Continued on page 808)

Around the Sections

(Continued from page 801)

Mines, Butte. Guest speaker was John McCaslin, assistant professor of physics at the school, who discussed *Instrumentation in the Mineral Industry.* The Section also attended a showing of the film, *Hemo the Magnificent*, on March 25 at the Museum Hall of the school.

***Milling and Smelting*—the Sudbury Nickel Ores—is a 16-mm sound color film produced by Inco, available free of charge. The 54-min movie combines animation and models with actual photography, presenting a complete picture of the operation. In addition, the history and formation of the Sudbury Basin deposit is described and the combined efforts of research engineers, technicians, and workers to solve the riddle of the rock, is shown.**

Inco's earlier film, *Mining for Nickel*, a 16-mm sound color film of 45-min duration, was reviewed in MINING ENGINEERING, October 1955. Both films are free and may be obtained from the distributor, Rothacker Inc., 729 Seventh Ave., New York 19, N. Y. State first, second, and third choice of showing date.

Coal Div. Bylaws

(Continued from page 798)

for one or more offices to the Executive Committee, and the persons so nominated shall be included in the official ballot.

Section 5. The election procedure of the Coal Division shall follow, and be consistent with, the procedure followed by the Institute.

Section 6. *Appointment of the Coal Division representatives to the Board of Directors and committees of the Society of Mining Engineers of AIME shall be made by the Chairman-Elect of the Division subject to the advice and approval of the Executive Committee of the Coal Division.*

Article VIII

Amendments

Section 1. Proposals to amend these Bylaws shall be made in writing to the Executive Committee. They shall be considered by the Executive Committee and announced to the members through the columns of "the appropriate Institute publication representing the Coal Division," together with any comments or amendments made by the Executive Committee thereon. They shall be voted upon at the annual meeting of the Division in February or by letter ballot, as may be directed by the Executive Committee, *subject to the approval of the Board of Directors of the Society of Mining Engineers of AIME and the AIME Board of Directors.*

Personals

(Continued from page 807)

president. Mr. Kingsbury, who was vice president and general manager, Rustless Iron & Steel Corp., prior to the incorporation of that company into Armco, will continue in a consulting capacity to Armco Steel Corp. **J. William Bryant,** who will assume Mr. Kingsbury's duties, has been elected a vice president. Associated with Armco for the past 33 years, he has been serving as controller and assistant treasurer in the Cleveland office.

R. FORD

Robert Ford, consulting geologist in Riverton, Wyo., is now associated with **Blake Fox,** a petroleum geologist, in the firm of Ford and Fox. Also affiliated with the firm are **Robert Beseda** and **Jack O'Leary.**

B. FOX

Changes in management staff were recently announced by American Smelting & Refining Co. Retiring are **Roger W. Straus,** chairman of the board, who will remain as a director, and **John C. Emison,** finance committee chairman. **Oscar S. Straus** will act as chairman to succeed Mr. Emison, while **Kenneth C. Brownell** has advanced to board chairman from president; **R. Worth Vaughan** has been elected president; **Forrest G. Hamrick,** the new treasurer, and **R. D. Bradford,** vice president, have been elected directors of the organization; **Kershaw Harms** will serve as vice president.

Felix E. Wormser has resigned as Assistant Secretary of the Interior. Mr. Wormser, who was vice president of St. Joseph Lead Co., New York, prior to entering Government service in 1953, has rejoined St. Joe. He has resumed his post with the company as vice president.

Allen F. Agnew has been appointed state geologist and director of the South Dakota Geological Survey. He teaches advanced and graduate geology courses at the University of South Dakota, Vermillion.

Louis S. Cates has been made a Knight Commander of the Agricultural and Industrial Order of Merit (Cuba). This honor was conferred upon him on May 9 in Havana.

E. L. J. Potts, holder of the Milburn Chair of Mining at the University of Durham, England, gave a series of lectures recently at the School of Mines and Metallurgy, University of Minnesota. Prof. Potts, who is a consultant to the National Coal Board of England, the Kolar Gold Mines of India, and the mining companies of the Rand in Africa, delivered the Warren Lecture at the school on May 15. His talk, entitled *Scientific Measurements in Strata Control,* dealt with the development of strain and sound measurement devices for better design of mine openings. **Otto Rellensmann,** dean of the Mining Academy, Clausthal, Germany, lectured at the school during the week of April 28 to May 5. His subjects concerned mine subsidence and the gyroscope in mining. Both men presented papers at the Second Annual Rock Mechanics Symposium (April 21-24) at the Colorado School of Mines.

G. R. Griswold has been admitted as a partner in the New Mexico engineering firm of Chapman & Wood. A graduate of the New Mexico School of Mines, Mr. Griswold has had wide experience in the area.

Mark A. Vendon, a recent graduate of the college of mines of the University of Arizona, has become a junior mining engineer at the Copper Queen Mine, Bisbee, Ariz.

Roy H. Glover, chairman of the board of directors, The Anaconda Co., delivered the 57th annual commencement address at Montana School of Mines on June 7th. During the graduation ceremony, Mr.

Glover was awarded the honorary degree of doctor of laws honoris causa.

S. H. REED, JR.

Sam H. Reed, Jr., has been appointed manager of the Chilete Unit of Northern Peru Mining Corp., a subsidiary of American Smelting & Refining Co. in Paredones, Peru. **Victor F. Hollister** has also joined the unit.

Harold H. Christy, superintendent of the Water and Power Dept., Colorado Fuel & Iron Corp.'s Pueblo plant, has been appointed chairman of the 1957 water committee of the Pueblo Chamber of Commerce. This group works mainly on the Fryingpan-Arkansas diversion project.

H. S. WINGATE

Henry S. Wingate, president of International Nickel Co. of Canada Ltd., was awarded the honorary degree of doctor of laws at the annual convocation of the University of Manitoba. The citation paid tribute to Inco's program for aid to higher education in Canada and also its role in the development of northern Manitoba by the opening of two nickel mines at Thompson and Moak Lake.

Perry R. Smoot, formerly a second lieutenant at Aberdeen Proving

Ground, Aberdeen, Md., is employed by the Ford Motor Co., Dearborn.

Philip J. Hastings has transferred from Pittsburgh to the New York office of National Carbon Co., a division of Union Carbide Corp.

R. F. Gray has resigned as mill superintendent, Mt. Morgan Ltd., Queensland, Australia, to become manager, technical services and sales, Mining Div., Timbrol Ltd., Sydney, Australia.

I. L. Barker has transferred to the New York office of Cerro de Pasco Corp. He was formerly located in La Oroya, Peru.

David W. Mitchell is manager of minerals research, Foote Mineral Co., Kings Mountain, N. C. He had been acting as vice president and technical director, the Oil Shale Corp., Beverly Hills, Calif.

John H. Bassarear has been appointed mill superintendent at National Lead Co.'s MacIntyre Development, Tahawus, N. Y. Prior to his appointment Mr. Bassarear was sinter plant superintendent.

Charles C. Boley has become coal technologist, USBM, Denver Federal Center, Denver. He was recently separated from active duty in the U. S. Army.

S. A. EASTON

Stanly A. Easton recently retired as chairman of the board of The Bunker Hill Co. and was named honorary chairman and director emeritus. Mr. Easton had been board chairman since 1954 and president of the company for 21 years prior to that time. He began his long association with Bunker Hill in 1903 in underground operations, and later that year became general manager. Born in Santa Cruz, Calif., Mr. Easton is a graduate of the College of Mines, University of California. Prior to his association with The Bunker Hill Co., he had worked as a laborer in metallurgical plants in Montana and California. A lifelong friend of Herbert Hoover, Mr. Easton was a member of the Belgian Exchange Commission after World War I. In addition to his work at Bunker Hill, he has served as president of Caledonia Mining Co.; chairman of the board, Pend Oreille Mines and Metals; is a past-director of St. Joseph Lead Co.; and twice served as president of the Idaho Mining Assn. Mr. Easton is the recipient of honorary degrees from Whitman College, Walla Walla, Wash.; University of California; University of Idaho; and Idaho College.

L. H. Baumgardner is associated with Reynolds Surinam Mining Corp., Paramaribo, Surinam.

Conrad W. Thomas is temporarily affiliated with Russell Bryan & Associates, San Francisco.

Donald E. Pruss is associated with Southern Pacific Co. in San Francisco.

Alfred Petrick, Jr., is with Reynolds Metal Co., Kwakwani, British Guiana.

J. Leroy Smith, formerly employed by Jones & Laughlin Steel Corp. in the Ore Div., Wanakena, N. Y., is now quarry superintendent for Old Colony Crushed Stone Co., Quincy, Mass.

George F. Stott is with Minas Mochito, San Pedro Sula, Honduras.

James L. Calver, formerly with Florida Geological Survey, has accepted the position of Commissioner of Mineral Resources, Virginia Dept. of Conservation and Development. Dr. Calver will also serve as state geologist of Virginia, succeeding **William M. McGill** who retired in April.

St. Joseph Lead Co. has announced the following staff elections: **Norman H. Donald, Jr.,** manager of explorations; **C. DeWitt Smith,** assistant vice president; **Robert H. Ramsey,** assistant vice president; and **Donald K. Lourie,** secretary.

R. F. Helmke has announced that his headquarters has been moved to 24 California St., San Francisco.

Erle V. Daveler has been named chairman and **Richard C. Klugescheld** president of Mesabi Iron Co. Mr. Daveler, a director, had been president of the company. Mr. Klugescheld, also a director, is a former vice president and general counsel of Kennecott Copper Corp. **Arnold Hoffman,** a director, has been elected vice president of Mesabi.

C. Jay Parkinson has been elected a member of the board of directors of The Anaconda Co., New York. He was recently named general counsel for the company, and has been elected a director of the following Anaconda subsidiaries: Andes Copper Mining Co., Chile Exploration Co., and Chile Copper Co. He is also a vice president and director of Anaconda Aluminum Co. A native of Salt Lake City, Mr. Parkinson attended the University of Utah and graduated from its law school in 1934 with an LL.B. degree. He has been active as a partner in law firms in Salt Lake City and has served as counsel for such mining companies as Basic Magnesium Inc., Henderson, Nev.; International Smelting & Refining Co. and The Anaconda Co., Salt Lake City; Stauffer Chemical Co.; American Gilsonite Co.; Manganese Inc.; and United States Lime

C. J. PARKINSON

Products Corp. Mr. Parkinson is a member of the American Bar Assn. and the California, Utah, and Nevada Bar Assns.

C. E. REISTLE, JR.

Carl E. Reistle, Jr., Past-President of AIME, has been named executive vice president of Humble Oil & Refining Co., Houston. He had been a member of the board of directors and vice president in charge of the production department prior to his new appointment. Born in Denver, he is a graduate of the University of Oklahoma. Following graduation, Mr. Reistle joined the Petroleum Div., USBM, and during his years with the Bureau worked with D. B. Dow on solubility of gas in oil. A paper on the subject, published in *Mining & Metallurgy*, was a forerunner to work that followed on the problem. The discovery of the East Texas oil field in 1931 led to Mr. Reistle's transfer to the East Texas branch of the USBM. Operators in the field formed the East Texas Engineering Assn. in 1933 and invited him to become the first field chairman. As a result of his work with the association, Mr. Reistle was asked to become engineer-in-charge of the Petroleum Engineering Div., Humble Oil & Refining Co., one of the largest operators in the area. He subsequently became head of the division in 1940, manager of production in 1945, director in 1948, and vice president in 1955. During his tenure as President of AIME, Mr. Reistle took an active role in the reorganization of the Institute, which led to the change from the three-Branch structure to the present Society of Mining Engineers, Society of Petroleum Engineers, and The Metallurgical Society within AIME.

Judson H. Whitman has been appointed mining engineer in the Rare Earths and Thorium Div., Michigan Chemical Corp., Golden, Colo.

Lenox H. Rand, economic geologist with the U. S. Bureau of Mines in Pittsburgh, has been transferred to Minneapolis.

P. B. ENTREKIN

New appointments in the mining division, Bethlehem Steel Corp., Bethlehem, include **P. B. Entrekin** as director of the corporation and assistant vice president of the division, and **E. P. Leach,** division general manager. Mr. Entrekin, who has been general manager of the division since 1949, joined the company in 1926, and was vice president of the company's Chile operations from 1944 to 1949. Mr. Leach, assistant to the vice president of the mining division prior to his new appointment, joined the company in 1941 in Chile. He served there successively as mine superintendent, assistant manager, and vice president and manager.

E. P. LEACH

S. D. Strauss, American Smelting & Refining Co., New York, was elected president of the American Zinc Institute at the annual meeting of the board of directors in April. Vice presidents elected at that time are: **J. D. Bradley,** The Bunker Hill Co., San Francisco; **Clarence Glass,** Anaconda Sales Co., New York; and **H. L. Young,** American Zinc Sales Co., St. Louis. Continuing as treasurer and executive vice president and secretary, respectively, are **E. V. Daveler** and **J. L. Kimberley.** In addition to the officers named, the following were elected as directors: **R. B. Caples,** The Anaconda Co., New York; **R. L. McCann,** The New Jersey Zinc Co., New York; **G. W. Potter,** Potter-Sims Mines Inc., Joplin, Mo.; **H. I. Young,** American Zinc, Lead, & Smelting Co., St. Louis; **F. A. Wardlaw, Jr.,** International Smelting & Refining Co., Salt Lake City; **Miles M. Zoller,** The Eagle-Picher Co., Cincinnati; and **William J. Welch,** National Lead Co., New York.

Walter Hochschild, president of The American Metal Co. Ltd., has been elected chairman, effective August 1, to succeed **Harold K. Hochschild,** who is retiring after 44 years to become honorary chairman and director. At the same time, **Hans A. Vogelstein** will become president. He had been vice president and treasurer. **Herbert S. Cohen,** vice president and controller, will take charge of finance, **Donald J. Donahue,** assistant treasurer, will become treasurer, and **Erwin A. Weil,** assistant secretary, will be secretary. Elected to fill new directorships were **Thomas H. Bradford,** managing director of Selection Trust Ltd., London, and **Henry T. Mudd,** president, Cyprus Mines Corp., Los Angeles.

L. J. Bechaud, Jr., Newmont Exploration Ltd., Grass Valley, Calif., has joined the company's metallurgical department in Danbury, Conn.

P. V. G. Ford has left England to join Beralt Tin & Wolfram Ltd., Minas da Panasqueira, Portugal.

William S. Van Meter, formerly with National Lead Co., Tahawus, N. Y., has joined Orinoco Mining Co., Ciudad Bolivar, Venezuela.

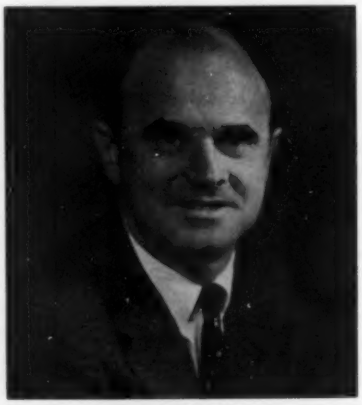
William B. Hall, general manager, has been named president and general manager, Vitro Uranium Co., Salt Lake City, a division of Vitro Corp. of America. A graduate of Princeton University, Mr. Hall had served with Sinclair Refining Co., East Chicago, Ill., and Southern Oil Co., Annapolis, Md., prior to joining Vitro in 1951 as project engineer. **Richard C. Cole,** assistant general manager, has been named vice president. He is a graduate of the University of Washington, and served with American Smelting & Refining Co. before joining Vitro in 1954 as plant manager of the uranium mill at Salt Lake City.

Members of Behre Dolbear & Co. Inc., New York, are on foreign assignments. **Parke A. Hodges** and **Chester M. F. Peters** are in Nicaragua. **Theodore B. Counselman, Elliott E. Check,** and **B. H. McLeod** are conducting a mine examination in Chile. **A. F. Banfield** has been in Cuba on a geological mission. He recently spent three months observing core drilling operations to a depth of 3400 ft in the potash project of International Minerals & Chemical Corp., Saskatchewan, Canada.

Edward E. Slowter has been elected a vice president of Battelle Memorial Institute, Columbus, Ohio. Prior to his new appointment, Mr. Slowter was secretary and business manager.

David W. Pinkard, a graduate of the University of Idaho in 1956, has joined American Smelting & Refining Co., El Paso, Texas.

Three professional degrees were awarded by the Montana School of Mines on June 7. Recipients and their degrees are: **Frank H. MacPherson,** engineer of mines; **Plato Malozemoff,** engineer of mines; and **Joseph T. Roy,** metallurgical engineer. Mr. MacPherson, a Colorado consultant, is general manager, vice president, and director, Dulaney Mining Co., Grand Junction, Colo. Mr. Malozemoff is president, Newmont Mining Co., New York. Mr. Roy is general manager, American Smelting & Refining Co., St. Helena, Mont., plant. Professional degrees are awarded by the Montana School of Mines to those graduates who have, over a five to ten-year period, established a professional career of which five years have been in a responsible capacity, and who have contributed in an outstanding manner to furtherance of the profession.



T. M. WARE

Thomas M. Ware, administrative vice president, International Minerals & Chemical Corp., Chicago, has been elected a director to succeed **David M. Milton,** who had served as a director for 15 years.

R. W. Diamond, retired executive vice president (western region) of the Consolidated Mining & Smelting Co. of Canada Ltd., Trail, B. C., has been awarded the 1956 Gold Medal of the Institution of Mining and Metallurgy (London) "in recognition of his distinguished services to the minerals industry in Canada."

in mining administration, awarded

Cornell became vice president of the

A former president of CIM, he is currently president of the Sixth Commonwealth Mining and Metallurgical Congress to be held in Canada this year. The Congress convenes in Vancouver, B. C., on September 8, and delegates will then spend the next 32 days visiting principal mining, metallurgical, and petroleum installations, and major cities in Canada, closing the Congress in Halifax, N. S., on October 9.

David O. Pearce is now associated with O'Kiep Copper Co. Ltd., Nababeep, Cape Province, South Africa.

I. R. M. Chaston has left General Mining & Agency Co. Ltd., where he was mill superintendent in South Thailand, to become research officer with the Dept. of Mines, Research Div. in Malaya.

Luis A. Jauregui has joined the Cía Minera del Cerro Negro, S. A., Monterrey, Mexico, as superintendent of operations. He was formerly chief mining engineer, Lance Engineers Inc., El Paso, Texas.

Arnold D. Asman, head of the Dept. of Mining, Pennsylvania State University, has been appointed product manager of mining equipment sales, Hewitt-Robins Inc., Stamford, Conn.

R. C. Flegal will be in charge of the new district office of the Bituminous Coal Institute to be opened in Buffalo. Mr. Flegal, a graduate of Pennsylvania State University, was formerly employed in the Institute's Philadelphia office.

R. F. Goodwin has been elected president of the Peruvian-American Assn. Inc. Mr. Goodwin is chairman of the executive committee, Southern Peru Copper Corp. Prior to his present association he spent 35 years with American Smelting & Refining Co., the last nine years as vice president in charge of the Mining Dept. **Frank F. Russell,** chairman of the board, Cerro de Pasco Corp. will continue as vice president of the Association. **William B. Hughes,** U. S. Steel Export Co., was re-elected treasurer.

R. F. GOODWIN

Frederick W. Glowatsky, second from left, was the recipient of an award from the Old Timers Club for scholastic attainment in mining engineering at Lehigh University. Shown presenting the award, a gold watch, to Mr. Glowatsky are, left to right: M. D. Cooper, education director, National Coal Assn.; Mr. Glowatsky; E. R. Price, member of the U. S. Coal Mine Safety Board; and Dr. Robert T. Gallagher, head of the department of mining engineering at Lehigh University. The Old Timers Club is composed of men prominent in the coal industry and awards are presented annually to outstanding college seniors throughout this country. For other news of Old Timers awards, see page 801.

Donald W. Lindgren has been appointed chief mining geologist for the Northern Pacific Railway Co. with headquarters at St. Paul, Minn. Mr. Lindgren is supervising a staff engaged in the exploration and development of the company's mineral resources, exclusive of oil and gas. **Virgil W. Carmichael** has been appointed mining engineer in the company's Geology Div. His duties will be primarily administration of coal properties and inspection of operating mines from St. Paul to Seattle.

A. H. Shoemaker, general manager, Homestake Mining Co., Lead, S. D., is chairman of the national program committee for the 1957 Metal Mining and Industrial Minerals Convention of the American Mining Congress, scheduled for September 9 to 12 in Salt Lake City.

F. R. Thornton is now senior process engineer for Nickel Processing Corp., Nicaro, Oriente, Cuba.

Antonio Romo has joined Ingersoll Rand de Mexico.

Vincent N. Burnhart has been promoted from operations manager to general manager, E. J. Longyear Co., Minneapolis. Mr. Burnhart, who has been with the company since 1946, has been a director since 1952.

Joseph H. Reid has been appointed general manager, Titanium Div., National Lead Co. A vice president, director, and member of the company's executive committee, Mr. Reid joined National Lead in 1927.

John V. Beall, former AIME Manager of Publications and Editor of MINING ENGINEERING, is project engineer with Kaiser Aluminio Ltd. in Belem, Brazil. Mr. Beall had been with the AEC in Washington, until he joined Kaiser.

Robert D. Ferron, manager of the South American Div., Exploration Dept., Kennecott Copper Corp., has changed his headquarters from Lima, Peru, to Rio de Janeiro, Brazil.

Arthur C. Hall, former vice president, Southern Peru Copper Corp., Lima, Peru, has returned to the U. S. and is now associated with American Smelting & Refining Co., Tucson, Ariz.

John Masters, head of the Calgary Alberta, office of Kerr-McGee Oil Industries Inc., Oklahoma City, Okla., has been awarded the George C. Matson Award at the annual convention of the American Assn. of Petroleum Geologists in St. Louis. The award was for presentation of his paper, *Ambrosia Lake Uranium Deposit*.

Joseph E. Kennedy, founder and board chairman of Kennedy-Van Saun Mfg. & Engr. Corp., was honored on the occasion of his 94th birthday with a reception at which 500 employes were present. One of the highlights of the evening was the presentation of Mr. Kennedy's portrait by Fred O. Reedy (right), president, to the Kennedy family, represented by Byron Pyle (left) son-in-law of Mr. Kennedy, an interested onlooker during the ceremony.

OBITUARIES

Cornelius Francis Kelley

An Appreciation By

Clyde E. Weed

It is with great regret that I and the members of the staff of The Anaconda Co. have to record the death on May 12, 1957, of Cornelius Francis Kelley (Member 1905) former chairman of the board of The Anaconda Co., and with whom I have been associated for many years.

Cornelius Francis Kelley was born at Mineral Hill, one of the famous mining camps of Nevada, where his father was superintendent of a silver mine, on Feb. 10, 1875. He moved with his family to Butte, Mont., in 1883. Mr. Kelley's love for mining was inherited from his father and influenced by his early environment.

At the age of 17, he began his career in the copper industry as a member of one of Anaconda's surveying parties. He was graduated with an LL.B. from the University of Michigan in 1898. In 1901 he joined Anaconda's legal department in Butte.

Mr. Kelley's advancement with Anaconda was rapid. In 1908 he became general counsel, in 1911 a vice president and director, and in 1918 he became president. In 1940 he was elected chairman of the board, a post he held until his retirement to the position of chairman of the executive committee in May 1955. At the time of his death he was also a director of The Anaconda Co. and many of its subsidiaries.

Always able to look to the future with keen insight, Mr. Kelley was the dynamic factor in the formation of a business structure built by wise and courageous moves over the years. He played an important role in the purchase and consolidation of mining properties in Butte. With John D. Ryan, his leadership brought Anaconda into the nonferrous metals manufacturing business as the first copper mining company to establish a completely integrated organization from "mine to consumer." He helped bring about the highly important development of Chilean copper, resolutely steered his company through the great depression, and was proud of the organization's achievements in supplying America with sorely needed metals in two world wars. His valued counsel was sought by industry and government alike. He was honored by all of us—for deep and broad humanitarianism and for moral awareness of the responsibility to the nation of those who force the earth to yield up her treasures.

The second AIME Charles F. Rand Medal for distinguished achievement in mining administration, awarded to Mr. Kelley in 1944, aptly summarizes the respect held for him by those of us who were privileged to serve him through the years. The citation reads: "For conspicuous success as administrative head of great enterprises engaged in the production of nonferrous metals at home and abroad; for inspiring leadership of an organization that has trained able engineers for service wherever ores are mined and metals are recovered; for enhancing the prestige of metal mining in the financial and industrial world."

Mr. Kelley was a leader in Catholic affairs. For many years he was a trustee of St. Patrick's Cathedral, New York, and was a member of the Knights of Malta, Equestrian Order of the Holy Sepulchre, and Knights of Columbus (Fourth Degree). Mr. Kelley was one of the recipients of the Gold Medal of the Mining and Metallurgical Society of America. His honorary degrees included: doctor of science from Michigan College of Mining and Technology in 1930; LL.D. from Montana School of Mines in 1936; doctor of commercial science from New York University in 1950; and LL.D. from Fordham University in 1955.

R. T. Cornell

An Appreciation By

Robert H. Ramsey

The passing, on Feb. 16, 1957, of Russell T. Cornell (Member 1902) brought to a close the career of a mining engineer of singular warmth and friendliness, as well as of great technical ability. He was a member of AIME for 55 years, and in that time he made a host of friends in those countries to which his mining activities took him.

Mr. Cornell graduated from the School of Mines of Columbia University with an M.E. degree in 1901. His first job was as a laborer at the Copper Queen smelter of Phelps Dodge Corp. in Arizona. He later became assistant chemist and also served as chief engineer on construction jobs. In 1904, he was manager of a small mine in Cuba, and a year later joined L. Vogelstein & Co. as exploration engineer. After four years, he explored independently for mines, and in 1910 he joined Adolph Lewisohn & Sons, devoting most of his time to exploration in Canada. His principal connection in this period was with the Kerr Lake mine.

In 1917, Mr. Cornell became manager of exploration for St. Joseph Lead Co., New York. This work took him to all quarters of the western hemisphere. In the years following 1930, he was engaged in exploration in Argentina for the Cía Minera Aguilar, the St. Joe affiliate there. After the death of Arthur F. Bennett, president of Cía Minera Aguilar, Mr. Cornell became vice president of the company. He remained in Argentina in that position until his retirement in 1949.

Mr. Cornell's work in Argentina was highly effective. Under his guidance the company developed a capable operating and managerial staff and was able to steer a safe course through the initial era of the Peron government. Mr. Cornell is remembered as an excellent administrator and a thoughtful, understanding gentleman with whom to work. The qualities of tact and cheerfulness that he brought to his work in South America were much appreciated by the Argentine people with whom he came in contact. The high regard that the Aguilar Co. enjoys there stems in large measure from the capability with which Mr. Cornell handled what was at times a most difficult and trying task. His work is much appreciated, and his loss was keenly felt by his friends and associates.

John B. Hicks (Member 1953) died Nov. 26, 1956. Former transportation engineer, Philadelphia & Reading Coal and Iron Co., he was a graduate of the University of Tennessee. His early career included jobs as construction engineer with Ford, Bacon and Davis, New York; Asher Coal Mining Co., Varilla, Ky.; Kentucky Utilities Corp., Lexington, Ky.; and Consolidation Coal Co., Fairmont, W. Va. In 1929, he joined Philadelphia & Reading, where he managed equipment for anthracite mines and preparation plants.

Gerardo Heimpel (Member 1951) passed away on Aug. 31, 1956. Born in Kressbronn, Germany, on Jan. 19, 1886, his career has included managerial posts in three South American mining firms, which he held up to the time of his death, and a role as manager, Heimpel Investment Co., since 1933. He became president, Chihuahua Mining Assn. in 1950.

J. Gordon Hardy (Member 1894) died on Dec. 14, 1956, from a heart attack. The 83-year old retired president of Falconbridge Nickel Mines Ltd. was a graduate of Glasgow Technical College, Scotland. Prior to joining Falconbridge in 1936, he had been vice president, Mining & Development Corp., New York, and Ventures Ltd., Toronto. His career also included positions with American Smelting & Refining Co. and Mexican International Corp., where he was manager in 1919.

Roger I. C. Manning (Member 1949) died Dec. 8, 1956. He was 57 years old. Born in Bladensburg, Md., he received his B.S. degree at the Missouri School of Mines in 1921. He held positions with the U. S. Bureau of Standards, Bunker Hill and Sullivan Mining & Concentrating Co., and became associate mining engineer, USBM, Salt Lake City. After

serving as field engineer, Arizona Dept. of Mineral Resources, Phoenix, he became director in 1949, occupying that post until his death.

Sanford E. Blamey (Member 1955) died on Sept. 2, 1956, at the age of 58. A native of Denver, Colo., he graduated from the Colorado School of Mines. After travelling to Ecuador, Honduras, Mexico, and California in various engineering capacities, Mr. Blamey returned to the Colorado Plateau area and a job with U. S. Vanadium Co. (now Union Carbide Nuclear Co.) in 1942. He held the post of superintendent of mines until his retirement in May 1956, serving consequently as consultant for the company on geological and mining problems.

Ralph C. Nicholson, Jr. (Member 1952) was killed in an accident on Oct. 15, 1956. The 27-year old Oklahoma University graduate had been working in Tyler, Texas, following his discharge from the U. S. Navy. Prior to his death, he was assistant engineering officer, Junior Exploration Geophysicists.

Arnold Ziffzer (Member 1944) died Dec. 17, 1956. A graduate of the Polytechnic Institute of the University of Kiev, Russia, and former student at the Université de Liège, Belgium, and the Mining Academy of Freiberg, Germany, he had been a consulting mining engineer in Arkansas prior to his death at the age of 69. From 1920 to 1940, Mr. Ziffzer had been engaged in excavation and scientific work in Germany. His association with U. S. institutions and mining companies included Hanna Coal Co., Battelle Memorial Institute, Curtiss-Wright Corp., and McNally Pittsburg Mfg. Corp.

Max W. Dessau (Member 1954) died Dec. 12, 1956. A native of Riverside, Calif., where he was born Sept. 25, 1902, Mr. Dessau had been associated with Climax Molybdenum Co. as mill superintendent and research metallurgist. He graduated from the Colorado School of Mines in 1926 and joined Climax in 1935. In 1938 he became a metallurgist for Patino Mines, and later joined Companie Mineral de Minas in Bolivia, returning to Climax in 1942. As an employe of that company, he made great contributions to its milling operations, and was the author of a number of technical publications.

Clarence V. Saylor (Member 1953) died suddenly in Butte, Mont., at the end of a meeting of the Montana Section, at which he presided as chairman. Although a comparatively new member of AIME, he was active in Institute affairs, serving on the Program Committee in addition to his duties as section chairman. A native of Talmadge, Kan., he was born on Dec. 4, 1908, and graduated from the University of Kansas in

1925 with a B.S. degree in chemical engineering. He began his 31-year career with the Great Falls Reduction Dept., The Anaconda Co., that same year, and was promoted from foreman to superintendent, and finally General Supt., Great Falls Reduction Dept. in March 1956.

He was very active in civic affairs, especially in the Red Cross Program, having served as county chairman for several terms. A past-president of the local Lions Club, he was also an ardent horseman, owning some very fine Arabian horses.

Mr. Saylor is survived by his wife, Faye; a son, Captain Kenneth, of the U. S. Air Force; and one grandson.

Clarence G. Willard (Member 1931) passed away recently in Denver, following a serious illness of almost a year. A recognized authority in the ore-grinding field, Mr. Willard was born in Deadwood, S. D., and received his B.S. and metallurgical engineering degrees at the South Dakota School of Mines. His first job was with Lundberg, Dorr & Wilson Co. as mill man. In 1914 he joined the Golden Reward Mining Co. at Terry, S.D., beginning as metallurgist, later becoming master superintendent. He also did consulting work prior to his association with the Mine & Smelter Supply Co., Denver, where he was manager of the Marcy Mill Div. Subsequently, he became executive vice president and director of Colorado Iron Works Co., a division of Mine & Smelter. A member of the American Mining Congress, Mr. Willard was also active in the Colorado Mining Assn. He is survived by his wife, five children, and six grandchildren.

Frank J. Cole (Member 1948) died Dec. 30, 1956. Born in Ashley, Pa., in 1903, he began his mining career as breaker boss with Glen Alden Coal Co., advancing to superintendent of the company's Hampton Coal Storage Yard in 1929. After appointments as fire boss, Maxwell Colliery, and breaker boss, Wanamie Breaker, he became responsible for the ten preparation plants of the company in Wilkes-Barre, Pa. In 1952 he was made assistant superintendent of construction.

Stanley L. Arnot (Member 1941) died recently. He was 68 years old. A graduate of the University of California, he received his early training as a surveyor's helper for North Star Mines Co., prior to becoming an engineer and superintendent, Plymouth Consolidated Gold Mines Ltd. He was an associate of Hamilton, Beauchamp & Woodworth from 1925 to 1927. In 1927, he was made superintendent of U. S. Lime Products Corp., Sonora, Calif., transferring to Sloan, Calif., in 1932.

Alfred W. G. Bleeck (Member 1910) died on Oct. 26, 1956. Born Nov. 14, 1883, in Calcutta, India, he earned a doctorate degree in Munich, Germany. A consulting and mining geologist for several years in Calcutta, he became manager and partner in the Rangoon firm of Mower & Co., Burma, in 1908. He was subsequently employed by the Indo Burma Petroleum Co., the London Rangoon Trading Co., and the British Burma Petroleum Co.

Corwin L. Cooper (Member 1940) died recently. A native of Pueblo, Colo., he was born on Sept. 3, 1890, and attended public schools in Pueblo and Denver. In 1914 he joined Simonds & Latham in California, working as a solution man, laboratory assistant, and sampler until his entrance into the U. S. Army. In 1921, he took the position of plant superintendent for Hamilton, Beauchamp & Woodworth in Jackson, Calif., subsequently traveling to Arizona and Nevada for mine rescue and investigation work. After a number of years as mine superintendent, Willow Creek Mines Inc., French Gulch, Calif., he became vice president of Knob Hill Mines Inc. in San Francisco.

Edwin B. Royle (Member 1945) died of a heart ailment, at his home in Saratoga, Calif., on Jan. 30, 1957. Born in Lehi, Utah, in 1905, he was the co-inventor of the Eimco Finlay Loader which he worked on from 1930-1932, while employed at the North Lily Mine in Eureka, Utah. Subsequently he was a field engineer and later chief designer of mining equipment for the Eimco Corp. Mr. Royle held more than 15 patents for Eimco Rocker Shovels.

Woodrow Knott (Member 1954) died of a heart attack Nov. 7, 1956. His age was 43. A native of Montrose, Colo., he graduated from Colorado University in 1936, beginning his career as a chemist for Climax Molybdenum Co. After five years with Dow Chemical Co., Midland, Mich., he joined Climax Uranium Co. in Grand Junction as plant metallurgist, advancing to plant manager and research director. Mr. Knott is survived by his wife and three daughters.

Ernest V. Faraggi (Member 1936) died in August 1956. Born on Dec. 31, 1879, he attended the Ecole Centrale des Arts et Manufactures, Paris, France, graduating in 1900. His first job was as mining engineer, Société des Mines de Kassandre, Greece, from which he progressed to manager, Anglo-French Ticapampa Silver Mining Co., Peru, later transferring to the Paris office. He was subsequently employed by the Société Miniere Francaise du Mercure de Ras-El-Ma, Algeria. Mr. Faraggi was a member of the Society of Civil Engineers of France and the Society of the Mineral Industry.

N. Porter Rhinehart (Member 1935) died Nov. 11, 1956, at the age of 64. Graduated from the University of Tennessee in 1914, he worked his way up within two years to a position in charge of mining engineering at Bon Air Coal & Iron Co., Bon Air, Tenn. In 1917 he supervised the P. M. Snyder mining interests at Mount Hope, W. Va., soon expanding his activities to include consulting work. In 1935 he became chief, Dept. of Mines, State of West Virginia, Charleston, and subsequently president, Charleston Coal Co.

Eugene E. Brossard (Member 1929) died on Sept. 19, 1956. A native of Ashland, Wis., where he was born on Dec. 30, 1896, Mr. Brossard attended the University of Wisconsin. Following graduation he took a job as assistant manager for Chivor Mines, Colombia, a division of the Colombian Emerald Syndicate. Employed by Venezuela Gulf Oil Co. in 1923, he was engaged in geological field work in the Maracaibo Lake basin, in addition to supervising the company's Ciudad Bolivar office. In 1948 he joined Aerovias Occidentales, San Jose, Costa Rica, where he served as geologist and manager until his death.

Victor C. De Munck (Member 1956) died in an airplane crash in El Salvador, Costa Rica, on Dec. 12, 1956. A native of Amsterdam, Holland, he was born on July 10, 1920, and graduated from the Geological Institute of the University of Amsterdam, receiving both his M.Sc. degree and doctorate there. In 1951 Dr. De Munck joined the Geological Mining Survey of Surinam, Dutch Guiana, as field and research geologist, where he served until 1954. After a brief stint with Reynolds Metal Co. as field geologist, U. S. Steel Corp. appointed him consultant geologist. In October 1955, he joined the staff of the Montana Bureau of Mines and Geology, whose Metals and Minerals Branch he headed until his premature death.

Joseph P. Gazzam (Legion of Honor Member 1884) died recently. Born in St. Louis, Mo., in 1861, he graduated from Washington University in 1884 and practiced as a mining engineer in St. Louis for many years.

Hale O. Davis (Member 1954) died recently. Born in Creede, Colo., on Mar. 5, 1896, he attended Benson Polytechnic in Portland, Ore. His position at the time of his death was mine accountant, Phelps Dodge Corp., Morenci, Ariz.

Eugene G. Saari (Member 1955), a graduate of West Virginia University in 1956, died recently. The mining engineering student had been working for Orinoco Mining Co. in Ciudad Bolivar, Venezuela.

Necrology

Date Elected	Name	Date of Death
1913	Waldo H. Comins	July 26, 1956
1951	William R. Dunn	Unknown
1956	George H. Evans	Sept. 30, 1956
1928	George W. Greenwood	March 1957
1943	Otto Haentjens	Mar. 31, 1957
1905	Cornelius F. Kelley Legion of Honor	May 12, 1957
1932	Frank H. Reed	Apr. 27, 1957
1954	Carl H. Vom Baur	May 28, 1957
1952	Frank Weir	Unknown
1913	Walter C. Mendenhall Honorary Member	June 2, 1957

MEMBERSHIP

Proposed for Membership
Society of Mining Engineers of AIME

Total AIME membership on May 31, 1957, was 27,379; in addition 2,972 Student Associates were enrolled.

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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Coming Events

July 27, AIME Adirondack Section, plant trip to Canadian Johns-Manville Co. Ltd., Asbestos, Que., and dance at Sherbrooke, Que., Canada.

Aug. 19-23, Sixth National Clay Conference, University of California, Berkeley, Calif.

Aug. 24, AIME Adirondack Section, golf and symposium on quality control in geology, mining, and milling, Country Club, Tupper Lake, N. Y.

Sept. 5-7, New Mexico Geological Soc., 8th annual field conference, Durango-Silverton-Ouray area, southwestern Colorado.

Sept. 8-Oct. 9, Commonwealth Mining and Metallurgical Congress, British Columbia to Nova Scotia, Canada.

Sept. 9-12, American Mining Congress, annual convention, Utah and Newhouse Hotels, Salt Lake City.

Sept. 13, AIME St. Louis Section, joint meeting with Amer. Chemical Soc. St. Louis Section. Hotel York, St. Louis.

Sept. 18-21, International Mineral Dressing Congress, Royal Inst. of Technology, Stockholm, Sweden.

Sept. 19, AIME Utah Section, *The Story of Mining and Milling at the Calera Mining Co., Cobalt, Idaho,"* by E. B. Douglas, manager of the company, Newhouse Hotel, Salt Lake City.

Oct. 3-5, Seventh Annual Exploration Drilling Symposium, University of Minnesota, Center for Continuation Study, Minneapolis.

Oct. 6-9, AIME Society of Petroleum Engineers, fall meeting, Adolphus, Baker, and Statler-Hilton Hotels, Dallas.

Oct. 10-11, ASME-AIME Coal Div., Joint Solid Fuels Conference, Chateau Frontenac, Quebec.

Oct. 15-18, AIME, Society of Mining Engineers Annual Meeting and Southeastern States Mining Conference, Hillsboro and Tampa Terrace Hotels, Tampa, Fla.

Oct. 30-Nov. 1, AIME Rocky Mountain Minerals Conference, Denver.

Nov. 8-9, AIME Central Appalachian Section, West Virginia Mining Inst., joint meeting, Greenbrier Hotel, White Sulphur Springs, W. Va.

Nov. 11-14, Society of Exploration Geophysicists, 27th annual meeting, Statler-Hilton Hotel, Dallas.

Feb. 16-20, 1958, AIME Annual Meeting, Hotel Statler, New York.

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